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FROM

The British Assoc. for

the Advancement of Science.

13 August, 1882.

REPORT

OF THE

ELEVENTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT PLYMOUTH IN JULY 1841.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1842.

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CONTENTS.

Page
Objects and Rules of the Association v
Officers and Council.. vii
Places of Meeting and Officers from commencement............... viii
Table of Council from commencement ix
Officers of Sectional Committees, and Corresponding Members xi
Treasurer's Account... xii
Reports, Researches, and Desiderata.............................. xiv
Recommendations for Additional Reports and Researches in Science xix
Synopsis of Money Grants xxiv
Arrangements of the General Evening Meetings xxv
Address of the President.. xxvii

REPORTS OF RESEARCHES IN SCIENCE.

On the Present State of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat. By the Rev. Philip Kelland, M.A., F.R.SS. Lond. and Edin., Professor of Mathematics in the University of Edinburgh, late Fellow of Queen's College, Cambridge .. 1

Report on Poisons. By G. L. Roupell, M.D., F.R.S. 26

Report on Discussions of Bristol Tides, performed by Mr. Bunt under the direction of the Rev. W. Whewell, F.R.S. 30

Report on the Discussion of Leith Tide Observations, executed by Mr. D. Ross, of the Hydrographer's Office, Admiralty, under the direction of the Rev. W. Whewell 33

Upon the working of Whewell's Anemometer at Plymouth during the past year. By W. S. Harris, Esq., F.R.S. 36

Report of a Committee, consisting of Sir J. F. W. Herschel, Bart., Mr. Whewell, the Very Rev. the Dean of Ely, Professor Lloyd, and Lieut.-Colonel Sabine, appointed for the purpose of superintending the scientific co-operation of the British Association in the system of Simultaneous Observations in Terrestrial Magnetism and Meteorology 38

Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord 41

Report of a Committee, consisting of Sir J. Herschel only, to superintend the reduction of Meteorological Observations.—July 1841 .. 42

Page

Report of a Committee, consisting of Sir J. HERSCHEL, Mr. WHEWELL, and Mr. BAILY, for revising the Nomenclature of the Stars........ 44

Report of a Committee appointed at the Glasgow Meeting of the British Association in September 1840, for obtaining Instruments and Registers to record shocks of Earthquakes in Scotland and Ireland.... 46

Report of the Committee for making Experiments on the Preservation of Vegetative Powers in Seeds.................................. 50

On Inquiries into the Races of Man, by Dr. HODGKIN 52

Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable Expense of such Experiments, and to draw up Directions for Observers in such circumstances 55

Report on British Fossil Reptiles. By RICHARD OWEN, Esq., F.R.S., F.G.S., &c. &c.. 60

Reports on the Determination of the Mean Value of Railway Constants 205

Second and concluding Report on the Determination of the Mean Value of Railway Constants. By DIONYSIUS LARDNER, LL.D., F.R.S., &c. 205

Report on Railway Constants. By EDWARD WOODS 247

Report of a Committee appointed at the Tenth Meeting of the Association, on the Construction of a Constant Indicator for Steam-Engines. Members of the Committee, the Rev. Professor MOSELEY, M.A., F.R.S., EATON HODGKINSON, Esq., F.R.S., J. ENYS, Esq. 307

Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals 325

Varieties of Human Race.—Queries respecting the Human Race, to be addressed to Travellers and others. Drawn up by a Committee of the British Association for the Advancement of Science, appointed in 1839.. 332

Observations made at the Magnetic Observatory at Toronto, during a remarkable Magnetic Disturbance on the 25th and 26th of September, 1841; with Postscripts, containing the Observations of the same Disturbance made at the Magnetic Observatories of Trevandrum, St. Helena, and the Cape of Good Hope........................ 340

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other Institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

MEMBERS.

All Persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution, recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Members of the Association, subject to the approval of a General Meeting.

SUBSCRIPTIONS.

The amount of the Annual Subscription shall be One Pound, to be paid in advance upon admission; and the amount of the composition in lieu thereof, Five Pounds.

An admission fee of One Pound is required from all Members elected as Annual Subscribers, after the Meeting of 1839, in addition to their annual subscription of One Pound.

The volume of Reports of the Association will be distributed gratuitously to every Annual Subscriber who has actually paid the Annual Subscription for the year to which the volume relates, and to all those Life Members who shall have paid Two Pounds as a *Book Subscription*.

Subscriptions shall be received by the Treasurer or Secretaries.

If the Annual Subscription of any Member shall have been in arrear for two years, and shall not be paid on proper notice, he shall cease to be a Member.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.
2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.
3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.
4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.
5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.
6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

OFFICERS AND COUNCIL, 1841—42.

Trustees (permanent).—Francis Baily, Esq. R. I. Murchison, Esq. John Taylor, Esq.

President.—Rev. Professor Whewell, F.R.S., V.P.G.S.

Vice-Presidents.—The Earl of Mount Edgecumbe. The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.

President Elect.—Lord Francis Egerton.

Vice-Presidents Elect.—John Dalton, D.C.L., F.R.S. Rev. Prof. Sedgwick, F.R.S. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart. Hon. and Rev. William Herbert, F.L.S. (Dean of Manchester).

General Secretaries.—R. I. Murchison, Esq., F.R.S. Colonel Sabine, F.R.S.

Assistant General Secretary.—John Phillips, Esq., F.R.S., York.

Secretaries for the Manchester Meeting in 1842.—Peter Clare, Esq. H. Fleming, M.D. James Heywood, Esq.

General Treasurer.—John Taylor, Esq., F.R.S., &c. 2 Duke Street, Adelphi, London.

Treasurer to the Meeting in 1842.—

Council.—G. B. Airy, Esq. H. T. De la Beche, Esq. Robert Brown, Esq. Rev. Dr. Buckland. Sir David Brewster. Dr. Daubeny. Sir Philip Egerton, Bart. Professor Forbes. Professor T. Graham. G. B. Greenough, Esq. Leonard Horner, Esq. W. J. Hamilton, Esq. Robert Hutton, Esq. Rev. W. V. Harcourt. Rev. Professor Lloyd. Rev. Dr. Peacock (Dean of Ely). The Marquis of Northampton. Rev. Dr. Robinson. Dr. Roget. Dr. Richardson. Sir John Robison. George Rennie, Esq. H. E. Strickland, Esq. Lieut.-Col. Sykes. Professor Wheatstone.

Local Treasurers.—Dr. Daubeny, Oxford. Professor Henslow, Cambridge. Dr. Orpen, Dublin. Charles Forbes, Esq., Edinburgh and Glasgow. William Gray, jun., Esq., York. William Sanders, Esq., Bristol. Samuel Turner, Esq., Liverpool. Rev. John James Tayler, Manchester. James Russell, Esq., Birmingham. William Hutton, Esq., Newcastle-on-Tyne. Henry Woollcombe, Esq., Plymouth.

Auditors.—William Yarrell, Esq. Leonard Horner, Esq. Robert Hutton, Esq.

I. Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

Presidents.	Vice-Presidents.	Local Secretaries.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.SS.L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
Sir T. MACDOUGAL BRISBANE, K.C.B., D.C.L., F.R.SS.L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.SS.L. & E., &c. Sir John Robison, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chan. Univ. Lond. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S.	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MOST NOBLE THE MARQUIS OF BREADALBANE. GLASGOW, September 17, 1840.	Very Rev. Principal Macfarlane Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Mount Edgecumbe The Earl of Morley Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	Wm. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, F.R.S. Richard Taylor, jun., Esq.
LORD FRANCIS EGERTON. MANCHESTER, to be held June 23rd, 1842.	John Dalton, D.C.L., F.R.S. Rev. A. Sedgwick, M.A., F.R.S. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart. Hon. and Rev. W. Herbert, F.L.S., &c.	Peter Clare, Esq. H. Fleming, M.D. James Heywood, Esq.

II. Table showing the Members of Council of the British Association from its Commencement, in addition to Presidents, Vice-Presidents, and Local Secretaries.

General Secretaries.	Rev. Wm. Vernon Harcourt, F.R.S., &c.	1832—1836.
	Francis Baily, V.P. and Treas. R.S.	1835.
	R. I. Murchison, F.R.S., F.G.S.	1836—1841.
	Rev. G. Peacock, F.R.S., F.G.S., &c.	1837, 1838.
	Lieut.-Colonel Sabine, V.P.R.S.	1839, 1841.
General Treasurer.	John Taylor, F.R.S., Treas. G.S., &c.	1832—1841.
Trustees (permanent).	Charles Babbage, F.R.SS.L. & E., &c. (Resigned.)	
	R. I. Murchison, F.R.S., &c.	
	John Taylor, F.R.S., &c.	
	Francis Baily, F.R.S.	
Assistant General Secretary.	Professor Phillips, F.R.S., &c.	1832—1841.

Members of Council.

G. B. Airy, F.R.S., Astronomer Royal	1834, 1835, 1841.
Neil Arnott, M.D.	1838, 1839, 1840.
Francis Baily, V.P. and Treas. R.S.	1837—1839.
H. T. De la Beche, F.R.S.	1841.
George Bentham, F.L.S.	1834, 1835.
Robert Brown, D.C.L., F.R.S.	1832, 1834, 1835, 1838—1841.
Sir David Brewster, F.R.S., &c.	1832, 1841.
Mark I. Brunel, F.R.S., &c.	1832.
Rev. Professor Buckland, D.D., F.R.S., &c.	1833, 1835, 1838—1841.
The Earl of Burlington	1838, 1839.
Rev. T. Chalmers, D.D., Prof. of Divinity, Edinburgh	1833.
Professor Clark, Cambridge	1838.
Professor Christie, F.R.S., &c.	1833—1837.
William Clift, F.R.S., F.G.S.	1832—1835.
J. C. Colquhoun, Esq.	1840.
John Corrie, F.R.S., &c.	1832.
Professor Daniell, F.R.S.	1836, 1839.
Dr. Daubeny	1838—1841.
J. E. Drinkwater	1834, 1835.
Sir Philip G. Egerton, Bart	1840, 1841.
The Earl Fitzwilliam, D.C.L., F.R.S., &c.	1833.
Professor Forbes, F.R.SS.L. & E., &c.	1832, 1841.
Davies Gilbert, D.C.L., V.P.R.S., &c.	1832.
Professor R. Graham, M.D., F.R.S.E.	1837.
Professor Thomas Graham, F.R.S.	1838, 1839, 1840, 1841.
John Edward Gray, F.R.S., F.L.S., &c.	1837—1839, 1840.
Professor Green, F.R.S., F.G.S.	1832.
G. B. Greenough, F.R.S., F.G.S.	1832—1839, 1840, 1841.
Henry Hallam, F.R.S., F.S.A., &c.	1836.
Sir William R. Hamilton, Astron. Royal of Ireland	1832, 1833, 1836.
W. J. Hamilton, Sec. G.S.	1840, 1841.
Rev. Prof. Henslow, M.A., F.L.S., F.G.S.	1837.
Sir John F. W. Herschel, F.R.SS. L. & E., F.R.A.S., F.G.S., &c.	1832.
Thomas Hodgkin, M.D.	1833—1837, 1839, 1840.
Prof. Sir W. J. Hooker, LL.D., F.R.S., &c.	1832.
Leonard Horner, F.R.S.	1841.
Rev. F. W. Hope, M.A., F.L.S.	1837.
Robert Hutton, F.G.S., &c	1836, 1838, 1839, 1840, 1841.
Professor R. Jameson, F.R.SS. L. & E.	1833.
Rev. Leonard Jenyns	1838.
H. B. Jerrard, Esq.	1840.

Dr. R. Lee ....1839.
Sir Charles Lemon, Bart.........................1838, 1839.
Rev. Dr. Lardner ....1838, 1839.
Professor Lindley, F.R.S., F.L.S., &c. ......1833, 1836.
Rev. Professor Lloyd, D.D. ....1832, 1833, 1841.
J. W. Lubbock, F.R.S., F.L.S., &c., Vice-
Chancellor of the University of London ...1833—1836, 1838, 1839.
Rev. Thomas Luby ....1832.
Charles Lyell, jun., F.R.S. ....1838, 1839, 1840.
William Sharp MacLeay, F.L.S...............1837.
Professor Miller, F.G.S. ....1840.
Professor Moseley.................................1839, 1840.
Patrick Neill, LL.D., F.R.S.E. ....1833.
The Marquis of Northampton, P.R.S.........1840, 1841.
Richard Owen, F.R.S., F.L.S...................1836, 1838, 1839.
Rev. George Peacock, M.A., F.R.S., &c. ...1832, 1834, 1835, 1839, 1840, 1841.
E. Pendarves, Esq. ....1840.
Rev. Professor Powell, M.A., F.R.S., &c. ...1836, 1837, 1839, 1840.
J. C. Prichard, M.D., F.R.S., &c. ....1832.
George Rennie, F.R.S. ....1833—1835, 1839, 1841.
Sir John Rennie......................................1838.
Dr. Richardson, F.R.S.............................1841.
Rev. Professor Ritchie, F.R.S. ....1833.
Rev. T. R. Robinson, D.D. ....1841.
Sir John Robison, Sec. R.S.E. ....1832, 1836, 1841.
P. M. Roget, M.D., Sec. R.S., F.G.S., &c....1834—1837, 1841.
Lieut.-Colonel Sabine ....1838.
Lord Sandon ....1840.
Rev. William Scoresby, B.D., F.R.SS. L. & E.1832.
H. E. Strickland, Esq., F.G.S...................1840, 1841.
Lieut.-Col. W. H. Sykes, F.R.S., F.L.S., &c.1837—1839, 1840, 1841.
H. Fox Talbot, Esq., F.R.S. ....1840.
Rev. J. J. Tayler, B.A., Manchester ....1832.
Professor Traill, M.D. ....1832, 1833.
N. A. Vigors, M.P., D.C.L., F.S.A., F.L.S...1832, 1836, 1840.
James Walker, Esq., P.S.C.E. ....1840.
Captain Washington, R.N. ....1838, 1839, 1840.
Professor Wheatstone ....1838—1841.
Rev. W. Whewell ....1838, 1839.
William Yarrell, F.L.S..........................1833—1836.

Secretaries to the Council. { Edward Turner, M.D., F.R.SS. L. & E. 1832—1836.
James Yates, F.R.S., F.L.S., F.G.S. 1831—1840.

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President.—John Taylor, Esq., F.R.S., &c.
Vice-Presidents.—Professor Moseley. J. S. Enys. J. M. Rendel.
Secretaries.—Henry Chatfield. Thomas Webster.

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Professor Agassiz, Neufchatel. M. Arago, Secretary of the Institute, Paris. A. Bache, Principal of Girard College, Philadelphia. Professor Berzelius, Stockholm. Professor H. von Boguslawski, Breslau. Professor De la Rive, Geneva. Professor Dumas, Paris. Professor Ehrenberg, Berlin. Professor Encke, Berlin. Baron Alexander von Humboldt, Berlin. M. Jacobi, St. Petersburgh. Dr. Lamont, Munich. Professor Liebig, Giessen. Professor Link, Berlin. Professor Œrsted, Copenhagen. M. Otto, Breslau. Jean Plana, Astronomer Royal, Turin. M. Quetelet, Brussels. Professor C. Ritter, Berlin. Professor Schumacher, Altona.

TREASURER'S ACCOUNT from

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in hand from last year's Account				309	11	6
Contributions from Members at Glasgow and since	790	0	0			
Subscriptions ...... Ditto ...... Ditto	1843	0	0			
				2633	0	0
Compositions for Books (future publications)				100	0	0
Dividend on £5000 3 per cent. Consols. 6 months, to January 1841	75	0	0			
Ditto £6000 ...... ditto ...... 6 months, to July last	90	0	0			
				165	0	0
Received on account of Sale of Reports, viz.						
1st vol., 2nd Edition	11	10	6			
2nd vol.	10	4	2			
3rd vol.	16	1	0			
4th vol.	15	9	9			
5th vol.	21	14	7			
6th vol.	32	1	2			
7th vol.	56	17	0			
Lithographs	0	8	0			
				164	6	2
				£3371	17	8

WILLIAM YARRELL,
ROBT. HUTTON, } AUDITORS.

31st August 1840 to the 24th July 1841.

PAYMENTS.

		£	s.	d.	£	s.	d.
Purchase of £1000, 3 per cent. Consols					898	15	0
Expenses of Meeting at Glasgow					300	0	0
Balance of Account for printing, &c. Ninth Report		144	1	11			
Paid on account of Tenth Report		9	2	9			
					153	4	8
Disbursements by General and Local Treasurers, Advertising, Sundry Printing, and publishing Reports					239	13	2
Salaries to Assistant Secretary, Accountant, and Clerk					177	10	0
Grants to Committees for Scientific purposes, viz.—for							
Experiments on Waves	1839	30	0	0			
Reduction of Stars in Histoire Céleste	„	50	0	0			
Meteorology, &c. Subterranean Temperature	„	8	8	0			
Acrid Poisons	„	6	0	0			
Experiments on Veins and Absorbents	„	3	0	0			
Marine Zoology	„	15	12	8			
Fossil Reptiles	„	50	0	0			
Foreign Scientific Memoirs	„	50	18	6			
Inquiries into the races of Men	„	5	0	0			
Anemometer at Edinburgh	„	60	0	0			
Forms of Vessels	„	193	12	0			
Skeleton Maps	„	20	0	0			
Radiate Animals	„	2	0	0			
Tabulating Observations on Subterranean Temperature, and Plate	„	9	6	3			
					503	17	5
Actinometers	1840	10	0	0			
Registering Earthquake Shocks	„	17	7	0			
Mud in Rivers	„	5	0	0			
Mountain Barometers	„	6	18	6			
Stars in Histoire Céleste	„	135	0	0			
Lacaille's Stars	„	79	5	0			
Nomenclature of Stars	„	17	19	6			
British Association Catalogue of Stars	„	40	0	0			
Action of Water on Iron	„	50	0	0			
Meteorological Observations at Inverness, &c.	„	20	0	0			
Reduction of Meteorological Observations	„	25	0	0			
Foreign Scientific Memoirs	„	11	2	0			
Railway Sections	„	38	1	0			
Meteorological Observations and Anemometers at Plymouth	„	55	0	0			
Magnetical Co-operation	„	61	18	8			
Fishes of Old Red Sandstone	„	100	0	0			
Tides at Leith	„	50	0	0			
Anemometer at Edinburgh	„	9	1	10			
					731	13	6
Balance in hands of Bankers		218	5	1			
Do. .... Treasurer and Local Treasurers		148	18	10			
					367	3	11
					£3371	17	8

British Association Property, 28*th July,* 1841.

	£	s.	d.
Balance of Cash in hand	£ 367	3	11
£6000 in 3 per cent. Consols. in the names of the Trustees, valued at 89¼	5385	0	0
Stock of Books on hand, estimated at	1203	6	0
	£6955	9	11

The following Reports on the Progress and Desiderata of different branches of Science have been drawn up at the request of the Association, and printed in its Transactions.

1831-32.

On the progress of Astronomy during the present century, by G. B. Airy, M.A., Astronomer Royal.

On the state of our knowledge respecting Tides, by J. W. Lubbock, M.A., Vice-President of the Royal Society.

On the recent progress and present state of Meteorology, by James D. Forbes, F.R.S., Professor of Natural Philosophy, Edinburgh.

On the present state of our knowledge of the science of Radiant Heat, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry, Oxford.

On Thermo-electricity, by the Rev. James Cumming, M.A., F.R.S., Professor of Chemistry, Cambridge.

On the recent progress of Optics, by Sir David Brewster, K.C.G., L.L.D., F.R.S., &c.

On the recent progress and present state of Mineralogy, by the Rev. William Whewell, M.A., F.R.S.

On the progress, actual state, and ulterior prospects of Geology, by the Rev. William Conybeare, M.A., F.R.S., V.P.G.S., &c.

On the recent progress and present state of Chemical Science, by J. F. W. Johnston, A.M., Professor of Chemistry, Durham.

On the application of Philological and Physical researches to the History of the Human species, by J. C. Prichard, M.D., F.R.S., &c.

1833.

On the advances which have recently been made in certain branches of Analysis, by the Rev. G. Peacock, M.A., F.R.S., &c.

On the present state of the Analytical Theory of Hydrostatics and Hydrodynamics, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of our knowledge of Hydraulics, considered as a branch of Engineering, by George Rennie, F.R.S., &c. (Parts I. and II.)

On the state of our knowledge respecting the Magnetism of the Earth, by S. H. Christie, M.A., F.R.S., Professor of Mathematics, Woolwich.

On the state of our knowledge of the Strength of Materials, by Peter Barlow, F.R.S.

On the state of our knowledge respecting Mineral Veins, by John Taylor, F.R.S., Treasurer G.S., &c.

On the Physiology of the Nervous System, by William Charles Henry, M.D.

On the recent progress of Physiological Botany, by John Lindley, F.R.S., Professor of Botany in the University of London.

1834.

On the Geology of North America, by H. D. Rogers, F.G.S.

On the philosophy of Contagion, by W. Henry, M.D., F.R.S.

On the state of Physiological Knowledge, by the Rev. Wm. Clark, M.D., F.G.S., Professor of Anatomy, Cambridge.

On the state and progress of Zoology, by the Rev. Leonard Jenyns, M.A., F.L.S., &c.

On the theories of Capillary Attraction, and of the Propagation of Sound as affected by the Development of Heat, by the Rev. John Challis, M.A., F.R.S., &c.

On the state of the science of Physical Optics, by the Rev. H. Lloyd, M.A., Professor of Natural Philosophy, Dublin.

1835.

On the state of our knowledge respecting the application of Mathematical and Dynamical principles to Magnetism, Electricity, Heat, &c., by the Rev. Wm. Whewell, M.A., F.R.S.

On Hansteen's researches in Magnetism, by Captain Sabine, F.R.S.

On the state of Mathematical and Physical Science in Belgium, by M. Quetelet, Director of the Observatory, Brussels.

1836.

On the present state of our knowledge with respect to Mineral and Thermal Waters, by Charles Daubeny, M.D., F.R.S., M.R.I.A., &c., Professor of Chemistry and of Botany, Oxford.

On North American Zoology, by John Richardson, M.D., F.R.S., &c.

Supplementary Report on the Mathematical Theory of Fluids, by the Rev. J. Challis, Plumian Professor of Astronomy in the University of Cambridge.

1837.

On the variations of the Magnetic Intensity observed at different points of the Earth's surface, by Major Edward Sabine, R.A., F.R.S.

On the various modes of Printing for the use of the Blind, by the Rev. William Taylor, F.R.S.

On the present state of our knowledge in regard to Dimorphous Bodies, by Professor Johnston, F.R.S.

On the Statistics of the Four Collectorates of Dukhun, under the British Government, by Col. Sykes, F.R.S.

1838.

Appendix to Report on the variations of Magnetic Intensity, by Major Edward Sabine, R.A., F.R.S.

1839.

Report on the present state of our knowledge of Refractive Indices for the Standard Rays of the Solar Spectrum in different media, by the Rev. Baden Powell, M.A., F.R.S., F.G.S., F.R.Ast.S., Savilian Professor of Geometry, Oxford.

Report on the distribution of Pulmoniferous Mollusca in the British Isles, by Edward Forbes, M.W.S., For. Sec. B.S.

Report on British Fossil Reptiles, Part I., by Richard Owen, Esq., F.R.S., F.G.S., &c.

1840.

Report on the recent progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science, by the Rev. Baden Powell, M.A., F.R.S., F.R.Ast.S., F.G.S., Savilian Professor of Geometry in the University of Oxford.

Supplementary Report on Meteorology, by James D. Forbes, Esq., F.R.S., Sec. R.S. Ed., Professor of Natural Philosophy in the University of Edinburgh.

1841.

Report on the conduction of Heat, by Professor Kelland, F.R.S., &c.

Report on the state of our knowledge of Fossil Reptiles, Part II., by Professor R. Owen, F.R.S.

The following Reports of Researches undertaken at the request of the Association have been published, viz.

1835.

On the comparative measurement of the Aberdeen Standard Scale, by Francis Baily, Treasurer R.S., &c.

On Impact upon Beams, by Eaton Hodgkinson.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Ireland, by the Rev. H. Lloyd, Capt. Sabine, and Capt. J. C. Ross.

On the phænomena usually referred to the Radiation of Heat, by H. Hudson, M.D.

Experiments on Rain at different Elevations, by Wm. Gray, jun., and Professor Phillips (Reporter).

Hourly observations of the Thermometer at Plymouth, by W. S. Harris.

On the Infra-orbital Cavities in Deers and Antelopes, by A. Jacob, M.D.

On the Effects of Acrid Poisons, by T. Hodgkin, M.D.

On the Motions and Sounds of the Heart, by the Dublin Sub-Committee.

On the Registration of Deaths, by the Edinburgh Sub-Committee.

1836.

Observations on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland, by Major Edward Sabine, R.A., F.R.S., &c.

Comparative view of the more remarkable Plants which characterize the Neighbourhood of Dublin, the Neighbourhood of Edinburgh, and the South-west of Scotland, &c.; drawn up for the British Association by J. T. Mackay, M.R.I.A., A.L.S., &c.; assisted by Robert Graham, Esq., M.D., Professor of Botany in the University of Edinburgh.

Report of the London Sub-Committee of the Medical Section of the British Association on the Motions and Sounds of the Heart.

Report of the Dublin Committee on the Pathology of the Brain and Nervous System.

Account of the Recent Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last meeting of the Association, by J. W. Lubbock, Esq.

Observations for determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media, by the Rev. Baden Powell, M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.

Provisional Report on the Communication between the Arteries and Absorbents, on the part of the London Committee, by Dr. Hodgkin.

Report of Experiments on Subterranean Temperature, under the direction of a Committee, consisting of Professor Forbes, Mr. W. S. Harris, Professor Powell, Lieut.-Colonel Sykes, and Professor Phillips (Reporter).

Inquiry into the validity of a method recently proposed by George B. Jerrard, Esq., for Transforming and Resolving Equations of Elevated Degrees; undertaken, at the request of the Association, by Professor Sir W. R. Hamilton.

1837.

Account of the Discussions of Observations of the Tides which have been obtained by means of the grant of money which was placed at the disposal of the Author for that purpose at the last Meeting of the Association, by J. W. Lubbock, Esq., F.R.S.

On the difference between the Composition of Cast Iron produced by the Cold and the Hot Blast, by Thomas Thomson, M.D., F.R.SS. L. & E., &c., Professor of Chemistry, Glasgow.

On the Determination of the Constant of Nutation by the Greenwich Observations, made as commanded by the British Association, by the Rev. T. R. Robinson, D.D.

On some Experiments on the Electricity of Metallic Veins, and the Temperature of Mines, by Robert Were Fox.

Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them.

Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body, by G. O. Rees, M.D., F.G.S.

Second Report of the London Sub-Committee of the Medical Section of the British Association, on the Motions and Sounds of the Heart.

Report from the Committee for making experiments on the Growth of Plants under Glass, and without any free communication with the outward air, on the plan of Mr. N. I. Ward, of London.

Report of the Committee on Waves, appointed by the British Association at Bristol in 1836, and consisting of Sir John Robison, K.H., Secretary of the Royal Society of Edinburgh, and John Scott Russell, Esq., M.A., F.R.S. Edin. (Reporter).

On the relative Strength and other mechanical Properties of Cast Iron obtained by Hot and Cold Blast, by Eaton Hodgkinson, Esq.

On the Strength and other Properties of Iron obtained from the Hot and Cold Blast, by W. Fairbairn, Esq.

1838.

Account of a Level Line, measured from the Bristol Channel to the English Channel, during the Year 1837–38, by Mr. Bunt, under the Direction of a Committee of the British Association. Drawn up by the Rev. W. Whewell, F.R.S., one of the Committee.

A Memoir on the Magnetic Isoclinal and Isodynamic Lines in the British Islands, from Observations by Professors Humphrey Lloyd and John Phillips, Robert Were Fox, Esq., Captain James Clark Ross, R.N., and Major Edward Sabine, R.A., by Major Edward Sabine, R.A., F.R.S.

First Report on the Determination of the Mean Numerical Values of Railway Constants, by Dionysius Lardner, LL.D., F.R.S., &c.

First Report upon Experiments, instituted at the request of the British Association, upon the Action of Sea and River Water, whether clear or foul, and at various temperatures, upon Cast and Wrought Iron, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Notice of Experiments in progress, at the desire of the British Association, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances, by Robert Mallet, M.R.I.A.

Experiments on the ultimate Transverse Strength of Cast Iron made at Arigna Works, Co. Leitrim, Ireland, at Messrs. Bramah and Robinson's, 29th May, 1837.

Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

1839.

Report on the application of the sum assigned for Tide Calculations to Mr. Whewell, in a Letter from T. G. Bunt, Esq., Bristol.

Notice of Determination of the Arc of Longitude between the Observatories of Armagh and Dublin, by the Rev. T. R. Robinson, D.D., &c.

Report of some Galvanic Experiments to determine the existence or non-existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alston Moor, by H. L. Pattinson, Esq.

Report respecting the two series of Hourly Meteorological Observations kept in Scotland at the expense of the British Association, by Sir David Brewster, K.H., LL.D., F.R.SS. L. and E.

Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle.

Third Report on the Progress of the Hourly Meteorological Register at the Plymouth Dockyard, Devonport, by W. Snow Harris, Esq., F.R.S.

1840.

Report on Professor Whewell's Anemometer, now in operation at Plymouth, by W. Snow Harris, Esq., F.R.S., &c.

Report on the Motions and Sounds of the Heart, by the London Committee of the British Association for 1839–40.

An Account of Researches in Electro-Chemistry, by Professor Schönbein, of Basle.

Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron, and Steel, by Robert Mallet, M.R.I.A., Ass. Ins. C.E.

Report on the Observations recorded during the Years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham. By A. Follett Osler, Esq.

Report respecting the two series of Hourly Meteorological Observations kept at Inverness and Kingussie, at the Expense of the British Association, from Nov. 1st, 1838, to Nov. 1st, 1839. By Sir David Brewster, K.H., F.R.S., &c.

Report on the Fauna of Ireland: Div. *Vertebrata.* Drawn up, at the request of the British Association, by William Thompson, Esq. (Vice-Pres. Nat. Hist. Society of Belfast), one of the Committee appointed for that purpose.

Report of Experiments on the Physiology of the Lungs and Air-tubes. By Charles J. B. Williams, M.D., F.R.S.

Report of the Committee appointed to try Experiments on the Preservation of Animal and Vegetable Substances. By the Rev. J. S. Henslow, F.L.S.

1841.

On the Tides of Leith, by the Rev. Professor Whewell, including a communication by D. Ross, Esq.

On the Tides of Bristol, by the Rev. Professor Whewell, including a communication by T. G. Bunt, Esq.

On Whewell's Anemometer, by W. S. Harris, Esq.

On the Nomenclature of Stars, by Sir John Herschel.

On the Registration of Earthquakes, by D. Milne, Esq.

On Varieties of the Human Race, by T. Hodgkin, M.D.

On Skeleton Maps for registering the geographical distribution of Animals or Plants, by — Brand, Esq.

On the Vegetative Power of Seeds, by H. E. Strickland, Esq.

On Acrid Poisons, by Dr. Roupell.

Supplementary Report on Waves, by J. S. Russell, Esq.

On the Forms of Ships, by J. S. Russell, Esq.

On Railway Constants, by Dr. Lardner.

On Railway Constants, by E. Woods, Esq.

On the Constant Indicator, by the Rev. Professor Moseley.

The following Reports and Continuations of Reports have been undertaken to be drawn up at the request of the Association.

On Salts, by Professor Graham, F.R.S.

On the Differential and Integral Calculus, by the Rev. Professor Peacock, M.A., F.R.S., &c.

On the Geology of North America, by H. D. Rogers, F.G.S., Professor of Geology, Philadelphia.

On Vision, by Professor C. Wheatstone, F.R.S.

On Isomeric Bodies, by Professor Liebig.

On Organic Chemistry, by Professor Liebig.

On Inorganic Chemistry, by Professor Johnston, F.R.S.

On the Salmonidæ of Scotland, by Sir W. Jardine.

On the Caprimulgidæ, by J. Gould, F.L.S.

On the state of Meteorology in the United States of North America, by A. Bache.

On the state of Chemistry as bearing on Geology, by Professor Johnston.

On Molluscous Animals and their Shells, by J. E. Gray, F.R.S.

On Ornithology, by P. J. Selby, F.R.S.E.

On the Specific Gravity of Steam, by a Committee, of which Mr. B. Donkin is Secretary.

On the recent progress and present condition of Electro-Chemistry and Electro-Magnetism, by Professor De la Rive, of Geneva.

On the state of our knowledge of the Zoology of New Zealand, by Dr. Richardson and J. E. Gray, Esq.

On the habits of the Radiata, by Sir C. J. Graham Dalzell, Bart.

On the resistance of the Atmosphere to Moving Bodies, by E. Hodgkinson, Esq.

On the progress of Astronomy during the present century, by the Astronomer Royal.

On the Theory of the Undulations of Fluid and Elastic Media, by Professor Kelland.

Recommendations for Reports and Special Researches, not involving Grants of Money, adopted by the General Committee at the Eleventh Meeting.

Resolved—

That the following Reports on the state of Science, formerly requested, be again asked for:—

1. The Astronomer Royal: Second Report on the Progress of Astronomy during the present century.
2. Professor Willis: Report on the State of our Knowledge of the Phænomena of Sound.
3. Professor Wheatstone: Report on Vision.
4. Professor Kelland: Report on the History and Present State of the Theory of Undulations of Fluid and Elastic Media.
5. Professor Bache: Report on the Meteorology of the United States.

That Mr. Gould be requested to report on the habits of the Caprimulgidæ, and that the Report be presented at the next meeting of the Association.

That Sir William Jardine be requested to continue his researches on the Salmonidæ, and that the Report be presented at a future meeting of the Association.

That a Committee, consisting of Dr. Richardson and Mr. Gray, be requested to report on the present state of our Knowledge of the Zoology of New Zealand.

The Report to be presented at the next meeting of the Association.

That Sir J. Dalzell be requested to report on the Habits of the Radiata; and that the Report be presented at the next meeting of the Association.

That Mr. Gray be requested to report on the Mollusca and their Shells; and that the Report be presented at the next meeting of the Association.

That Mr. Hodgkinson be requested to complete his Experiments on the Resistance of the Atmosphere to Moving Bodies; and to report the result to the next meeting of the Association.

Recommendations of Researches in Science involving Grants of Money, adopted by the General Committee at the Eleventh Meeting.

That the Committee already appointed on Calculation of Tides at Bristol (viz. the Rev. W. Whewell) by Mr. Bunt, be re-appointed; and that the sum of 20*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed on the Reduction of the Stars in the *Histoire Céleste* (viz. Mr. Baily, the Astronomer Royal, and the Rev. Dr. Robinson) be re-appointed; and that the sum of 65*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed on the extension of the Royal Astronomical Society's Catalogue (viz. Mr. Baily, the Astronomer Royal, and the Rev. Dr. Robinson) be re-appointed; and that the sum of 110*l.* (the residue of the former grant) be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed on the Reduction of Lacaille's Stars (viz. Sir John Herschel, the Astronomer Royal, and Mr. Henderson) be re-appointed; and that the sum of 105*l.* (being the unexpended balance of the former grant of 184*l.* 5*s.*) be placed at their disposal for the purpose.

That Mr. Whewell, Lord Adare, Dr. Robinson, Sir J. Robison, Mr. Scott Russell, the Astronomer Royal, Mr. Snow Harris, Hon. and Rev. Charles Harris, be a Committee for obtaining information respecting the Velocity of Sea Waves, and for drawing up instructions for making the requisite observations; and that the sum of 30*l.* be placed at their disposal for the purpose.

That Mr. Whewell, Colonel Sabine, Sir John Lubbock, the Astronomer Royal, and Mr. Snow Harris, be a Committee to procure observations of the Tides in the Pacific; and that the sum of 60*l.* be placed at their disposal for that purpose.

That a Committee, consisting of Professor Whewell, the Astronomer Royal, Professor Lloyd, Colonel Sabine, Professor Phillips, and Mr. Snow Harris, be appointed to make application to the Government for funds, for the publication of the series of Hourly Meteorological Observations which have been made for five years at Plymouth, at the expense of the Association, and to superintend the publication; and that in case of the failure of this application, the sum of 250*l.* be placed at the disposal of the same Committee, for the purpose of carrying this object into effect.

That a Committee, consisting of the Rev. Dr. Robinson, Colonel Sabine, Professor Wheatstone, Rev. W. Whewell, the Astronomer Royal, Sir John Herschel, and Sir John Lubbock, be appointed; for the purpose of conducting experiments, by captive Balloons, on the Physical Constitution of the Atmosphere.

The Report to be presented at the next meeting of the Association; and that the sum of 250*l.* be placed at the disposal of the Committee for the purpose.

That the grant of 60*l.*, placed at the disposal of Sir D. Brewster, Mr. Osler, and Professor Forbes, for erecting an Anemometer at Inverness, be continued.

That the sum of 40*l.* (including the remainder of the former grant) be placed at the disposal of Sir D. Brewster, for the purpose of continuing inquiries into the Action of Media upon the Solar Spectrum.

That the sum of 100*l.* be placed at the disposal of the Committee formerly appointed (consisting of Sir J. Herschel, Professor Whewell, Dr. Peacock, Professor Lloyd and Colonel Sabine), for conducting the co-operation of the Association in the system of simultaneous Magnetical and Meteorological Observations.

That the sum of 65*l.*, being the balance of a former grant, be placed at the disposal of Sir D. Brewster and Professor Forbes, for the purpose of revising and continuing the Hourly Observations at Inverness and Kingussie.

That there be placed at the disposal of Mr. W. Snow Harris:—

	£	*s.*	*d.*
For some new Experiments on the Force and Velocity of the Wind	10	0	0
For a continuation of the Observations, &c. with Whewell's Anemometer at Plymouth	8	0	0
For defraying the expense of Observations, &c. with Osler's Anemometer at Plymouth	25	0	0
For defraying the expense of the Hourly Observations of the Barometer, Thermometer, &c. at the Dockyard, Devonport	40	0	0
	£83	0	0

That the Committee formerly appointed to superintend the translation and publication of Foreign Scientific Memoirs be re-appointed (consisting of Colonel Sabine, Dr. R. Brown, Dr. Robinson, Sir J. Herschel, Professor Wheatstone, Sir D. Brewster, Professor Owen, Professor T. Graham, Professor Miller, Sir W. Jardine, Professor R. Graham); and that the sum of 88*l.* 18*s.* (being the residue of the grant of last year) be placed at the disposal of the Committee for the purpose.

That the balance of the grant of 100*l.*, for the reduction of Meteorological Observations (viz. 75*l.*), under the superintendence of Sir John Herschel, be continued.

That the balance of the grant of 50*l.*, viz. 32*l.* 0*s.* 6*d.*, for the revision of the Nomenclature of Stars, be continued to the Committee (consisting of Sir John Herschel, Professor Whewell, and Mr. Baily) formerly appointed for that purpose.

That the Committee already appointed, viz. Dr. Prout, Dr. T. Thomson, Professor Owen, Professor Graham, and Dr. R. D. Thomson, be requested to undertake a series of researches on the Chemistry and Physiology of Digestion; and that the sum of 200*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. R. Fox, Dr. Daubeny, and Mr. Robert Hunt, be requested to continue a series of Experiments on the Action of various coloured Rays of Light on the Germination of Seeds and the Growth of Plants; and that the sum of 15*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed (consisting of Mr. Bryce, Mr. De la Beche, and Major Portlock), for Experiments on the quantity of Mud suspended in the Water of Rivers under different circumstances, be requested to continue their inquiries; and that the sum of 20*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed (consisting of the President of the Royal Society, the Rev. Dr. Buckland, R. I. Murchison, Esq., John Taylor, Esq., H. T. De la Beche, Esq., C. Vignoles, Esq., with power to add to their number), for taking measures to obtain Coloured Drawings of Railway Sections before they are covered up, be requested to continue their labours; and that the sum of 150*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That Professor Johnston and Mr. Jeffreys be requested to repeat their experiments on the Solution of Silica in Water of a High Temperature; and that the sum of 25*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Dr. Buckland, Mr. L. Horner, Mr. Wheatstone, for England; Lord Greenock, Mr. Milne, Professor Forbes, Mr. Pattison, for Scotland; Capt. Portlock and Mr. Bryce for Ireland, be requested to register the Shocks of Earthquakes in England, Scotland, and Ireland; and that the sum of 100*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That Capt. Portlock be requested to continue his experiments on the Temperature of Mines in Ireland; and that the sum of 10*l.* be placed at his disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of the Marquis of Northampton, Dr. Buckland, and Professor Sedgwick, be appointed for the purpose of advancing our knowledge of Belemnites; and that the sum of 50*l.* be placed at the disposal of that Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That for the purpose of promoting the publication of the drawings requisite to the illustration of the Report on Fossil Reptiles, which was undertaken by Professor Owen, and is now completed, the sum of 250*l.* be placed at the disposal of a Committee, consisting of Mr. De la Beche, Mr. Hutton, Dr. Richardson, Mr. L. Horner, Col. Sabine, and Mr. Phillips.

That Professor Owen be requested to draw up a Report on the British Fossil Mammalia; and that the sum of 200*l.* be placed at the disposal of Dr. Richardson, Dr. Buckland, and Mr. Richard Taylor, for the purpose of defraying the necessary expense of visiting and collecting materials, making drawings, &c.

That the Committee already appointed (consisting of Dr. Prichard, Dr.

Hodgkin, Mr. J. Yates, Mr. Gray, Mr. Darwin, Mr. R. Taylor, Dr. Wiseman, and Mr. Yarrell), for preparing a series of questions on the Races of Men, be requested to continue their labours; and that the sum of 7*l.* 10*s.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That the Committee already appointed (consisting of Dr. Lankester, Dr. Arnott, Dr. Greville, and Dr. Fleming) to report on the Organic Beings of Mineral Waters, be requested to continue their researches, and that Dr. Daubeny, Mr. Forbes, and Mr. Goodsir be added to the number; and that the sum of 6*l.* be placed at their disposal for the purpose.

That a Committee, consisting of Mr. Hugh Strickland, Dr. Daubeny, Professor Lindley, and Professor Henslow, be requested to continue the investigations on the Growth and Vitality of Seeds; and that the sum of 10*l.*, formerly granted, be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. Babington and Mr. Garnons, be requested to continue the researches on the preservation of animal and vegetable substances; and that the sum of 6*l.*, formerly granted, be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Mr. Gray, Mr. Forbes, Mr. Goodsir, Mr. Patterson, Mr. Thompson of Belfast, Mr. Ball of Dublin, Dr. Geo. Johnston, Mr. Smith of Jordan Hill, Mr. Couch, Mr. Bartlett, Mr. H. Bellamy, Mr. Walker, and Mr. Lyte, be requested to undertake a series of researches with the dredge, with a view to the investigation of the Marine Zoology of Great Britain, the illustration of the Geographical Distribution of Marine Animals, and the more accurate determination of the Fossils of the Pleiocene Period; and that the sum of 50*l.*, placed at the disposal of the Committee last year for the purpose, be continued.

The Report to be presented at the next meeting of the Association.

That the sum of 150*l.* be granted for inquiries into Vital Statistics. The Committee to consist of Lieut.-Col. Sykes, Viscount Sandon, Mr. G. R. Porter, Mr. J. Heywood, Dr. W. P. Alison, Dr. Cowan, Mr. E. Chadwick, and Mr. Watts.

That the Committee already appointed on the Forms of Vessels (consisting of Sir J. Robison, Mr. Scott Russell, and Mr. J. Smith) be requested to complete their experiments on that subject; and that the sum of 150*l.* be placed at the disposal of the Committee for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Professor Moseley, Mr. Enys, and Mr. Hodgkinson, be appointed for completing the dynamometrical experiments on the Steam Engine, and for applying the chronometrical apparatus of Poncelet and Morin, to determine the velocity of the piston at different periods of the stroke; and that the sum of 100*l.* be placed at their disposal for the purpose.

The Report to be presented at the next meeting of the Association.

That a Committee, consisting of Professor Moseley, Mr. E. Hodgkinson, Mr. Brunel, and Mr. E. Woods, be requested to apply the Constant Indicator to Locomotive Engines on Railways; and that the sum of 100*l.* be placed at the disposal of the above Committee for the purpose.

The Report to be presented at the next meeting of the Association.

Synopsis of Sums appropriated to Scientific Objects by the General Committee at the Plymouth Meeting.

SECTION A.

	£	s.	d.
Hourly Meteorological Observations at Kingussie and Inverness	65	0	0
Tide Discussions: Leith	50	0	0
Tide Discussions: Bristol	20	0	0
Reduction of Meteorological Observations	75	0	0
Nomenclature of Stars	32	0	6
Stars in *Histoire Céleste*	65	0	0
British Association Catalogue of Stars	110	0	0
Erection of Anemometer at Inverness	60	0	0
Action of Gases on Light	40	0	0
Lacaille's Stars	105	0	0
Meteorological Observations at Plymouth	40	0	0
Whewell's Anemometer at Plymouth	8	0	0
Magnetic Co-operation	100	0	0
Scientific Memoirs	88	18	0
Velocity of Sea Waves	30	0	0
Tides in Pacific	60	0	0
Publication of Meteorological Observations	250	0	0
Experiments with Balloons	250	0	0
Force and Velocity of Wind	10	0	0
Osler's Anemometer at Plymouth	25	0	0
	£1433	18	6

SECTION B.

Chemistry and Physiology of Digestion	200	0	0
Action of Light on Growth of Seeds	15	0	0
	£215	0	0

SECTION C.

Mud in Rivers	20	0	0
Railway Sections	150	0	0
Subterranean Temperature in Ireland	10	0	0
Earthquake Registration	100	0	0
Solution of Silica in Water at High Temperatures	25	0	0
British Belemnites	50	0	0
Fossil Reptiles (Publication of Report)	250	0	0
	£605	0	0

SECTION D.

Preservation of Animal and Vegetable Substances	6	0	0
Marine Zoology	50	0	0
Plants and Animals in Mineral Waters	6	0	0
Vegetative power of Seeds	10	0	0
Races of Men	7	11	0
British Fossil Mammalia	200	0	0
	£279	11	0

SECTION F.

Vital Statistics	150	0	0

Section G.

	£	s.	d.
Dynamometric Instruments	100	0	0
Forms of Vessels	150	0	0
Constant Indicator to Locomotives	100	0	0
	£350	0	0

Total of Money Grants £3033 9 6

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, John Taylor, Esq., 2 Duke Street, Adelphi, London, for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the Members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include the specified balance which may remain unpaid on the former grant for the same object.

On Thursday evening, July 29th, at 8 P.M., the President, the Rev. W. Whewell, M.A., F.R.S., Professor of Moral Philosophy in the University of Cambridge, took the Chair in the Town Hall, Devonport, and read an Address (see next page).

On Friday evening, July 30th, in the same room, Mr. Chatfield, of H. M. Dock Yard, Devonport, gave an account of the construction and launching of ships, with reference to the launch of the Hindostan (80 guns) on Monday evening.

On Tuesday evening, August 3rd, Mr. Dent explained a new Clock; Dr. Reid illustrated his processes of Ventilation; Mr. De Moleyns exhibited a Voltaic Battery; and Mr. Brunel described the Thames Tunnel.

On Wednesday, at 8 P.M., the CONCLUDING GENERAL MEETING of the Association took place in the Town Hall, Devonport, when an account of the PROCEEDINGS OF THE GENERAL COMMITTEE was read by Colonel Sabine.

ADDRESS

BY

THE REV. PROFESSOR WHEWELL, F.R.S., &c.

Gentlemen,—It now becomes my business to take upon myself the office of President of the British Association, in virtue of my election to that situation, which took place at the meeting at Glasgow last year in the usual form. The election was made in my absence, and contrary to my expectation; but of my own views and feelings with regard to the wisdom of the choice then made, I shall not say one word. I will only remark, that any apprehension which I may entertain of my own unfitness for this office, and of the superior claims of others to the distinction, will have no other effect than that of making me more diligent and scrupulous in the discharge of my official duties, since those are the merits which are most within my reach, and for the want of which no eminence, either in science or in society, can compensate. It cannot but occur to those who are acquainted with the proceedings of the Association in past years, that it would be agreeable to the general course of its usage, if this Chair were occupied by some illustrious man of science belonging to this region of England; (the region does not want for such as by their powers and their European reputation might fitly be placed at the head of any scientific association in the world) or again, if it were occupied by some of those men of eminent rank and influence in the district and in the empire, who have shown, by their attendance here and by their services rendered to this meeting, their approbation of the objects of the British Association, and their good will towards its members. But if you had met under a President whose claims to your attention, however high, were of a merely local nature, while at the same time no one of the primary officers of the last meeting, the President and Vice-Presidents, were present, to transmit into his hands, by a visible act, the dignity of which I have the honour now to be the temporary holder, it might seem as if the continuity of the Association had been interrupted,—as if this were rather a new institution, arising in this district, than a new meeting of a body which has had, now for eleven years, a connected and unbroken existence. My hand may serve at least to transmit the torch from one place of assemblage to another,—to bring the sacred fire which has been lit and kept alive at the former meetings of our body, and to place it upon the altar which has been erected in this great maritime town. On one account, at least, I may venture to undertake such a ministry as this: I have been a faithful attendant upon the meetings of the Association ever since its first institution, and there is scarcely any subordinate office of labour or dignity in the constitution of the body which I have not at one place or other discharged, with such zeal and care as was in my power. However the Council may have judged well or ill in this selection, they have at least this excuse, that they have not gone out of their way to make it,—that they have not placed in this high office of the Association one whose willingness to serve it, and to be for the time identified with it, was at all doubtful, so far as past events could prove it.

In proceeding to the business of the Association, it is not my intention to attempt to give you any account of the arrangements and prospects of the present meeting, nor of the proceedings of the last, and the transactions of the intermediate time. In several preceding years, there has been laid before the first General Meeting of the Association a statement of the main contributions to science, which were included in the recent Proceedings of the body,—a survey and estimate of the scientific work done during the twelvemonth. This is a task always difficult, and sometimes long; and I believe many of you, who know the character which it almost necessarily assumes, of a collection of abridgments of papers on abstruse points of science, will not regret its being occasionally omitted. But perhaps I may be allowed to occupy you for a few minutes with a slight sketch of the general aspect which the Association now appears to me to offer to a thoughtful spectator;—of the place it holds among the characteristics, and I may say, the institutions of our time and country. Such a view of our position may serve to remind us of our duties to the Association, and to the great cause which it represents, and may guide and animate us in the discharge of them.

Those of you who are acquainted with the writings of the greatest of our philosophers, are aware that several of them, contemplating the past progress and future prospects of science in that spirit of comprehensive thought and large hope, which the subject so strongly calls for, have imagined some vast Institution, by which the advance of science should be systematically and powerfully aided;—some great Philosophical College, which should have for its business, not to teach mainly, but to make discoveries—to extend our knowledge of every part of nature by all the appliances which experiment and theory, observation and calculation, ingenuity and perseverance, can supply; and in addition to these, by more material resources, money and a multitude of fellow-labourers. You recollect, perhaps, the great Bacon's remarkable picture of the *New Atlantis*. The imaginary teacher, whom he introduces as one of the sages of this Utopian region, describes to the inquiring traveller an institution which he calls *Solomon's House*, and which is such a college for making discoveries as we have just spoken of. Of this institution, he says, "The end of our foundation is the knowledge of causes and secret motions of things, and the enlarging the bounds of the human empire to effecting of things possible." As parts of this house, there are described caves and wells, chambers and towers, baths and gardens, parks and pools, dispensatories and furnaces, and many other provisions for experiment and observation. There are also many classes of persons who conduct the business of this college, and whom, according to their employments, he calls by somewhat fanciful names—*merchants of light; mystery men; depredators; pioneers*, or *miners; compilers; dowry men*, or *benefactors; lamps; inoculators;* and finally, *interpreters of nature*, who elevate the truths of experiment into general laws, the highest forms of human knowledge.

Other philosophical writers have presented, in various ways, somewhat of the same conceptions. But, you will perhaps say, all this is mere imagination. Such an institution exists only in Utopia: it was never contemplated as a reality. True: it is ideal, just as all the highest forms of human institutions are ideal. It is Utopian, just as a perfect monarchy, perfectly administered, is Utopian. But if we conceive a perfect monarchy, where the sovereign has unlimited power, which he exercises with entire wisdom and justice, while the resources of the state are ample, and the character of the nation is intellectual and progressive, must we not, in such an Utopia, include also the notion of such a college of discovery? Beyond all doubt, if we imagine to ourselves a New Atlantis, we must also place in it a Solomon's House. Still, you will say, all is imaginary—and to what use do we feed our minds with these empty pictures of unattainable good? To what use, do you ask? Some of you, well aware that, in the constitution of man, imagination and hope,—the boldest imagination, the loftiest hope,—are not without their use —aware what that use is, have already answered this question in your own hearts. Of what use are the ideal pictures of objects that tend to elevate and improve the condition of man? Of that use, which, if we disregard, the condition of man forthwith becomes degraded, and his prospects a blank. They are of use in raising our thoughts and stimulating our exertions, so that we may become wiser, and better, and nobler than we are. Is this a new doctrine? God be thanked, in this country at least, it has long been familiar to men's minds—has been practically acted upon, and has been attended with the most blessed and glorious effects. Let us look to other objects, very different from the increase of knowledge, and we shall easily discern the operation of this doctrine. It is not difficult to see in what form we may expect to find it showing itself. For if we imagine this Utopia of a perfect government, Solomon's House will not be the only ideal institution there. In such a land of justice, and wisdom, and religion, we shall have colleges for diffusing justice, and wisdom, and religion over the face of the earth. We shall have a college for teaching the poor, a college for repressing the vicious, a college for the abolition of slavery, a college for diffusing Christianity over the face of the globe. Such colleges we should have in our Utopia—but Utopia is not. What then? do we therefore despair of these great objects? Do we sigh to think that all this contemplated good is mere imagination? Do we lament that we are not in an absolute monarchy, where the wisdom of the sovereign, supported by unlimited power, might call into existence those beneficial institutions? Do we despair of these great and good objects, because we live in a state of society where men act each for himself, unforced by supreme power? Do we cast away our ideas, because we are not likely to be carried towards their realization by the whole power of the state? Do we do this; or do we not do something very different? Something very different indeed we do. We still keep our thoughts fastened upon our ideas of what is highest and best; but feeling that we are free, and that it is our glorious privilege to act as freemen, we attempt to realize our ideas, not by the power of the state, but by that power which, in such a state and on such subjects, represents the conviction of the nation, the power of voluntary association. We have had thus,—not state colleges, but voluntary societies, —for Christianizing the Heathen, for teaching the ignorant, for repressing the vicious; and we *had* a voluntary Society for the Abolition of Slavery, till the principle of voluntary association, in that instance, thank God! performed its work even to the end, by inducing the State to take up and carry into effect the great object which had been the aim of the voluntary society from its foundation.

What, then, is the conclusion to which we are led, by looking at the spirit of our country, as shown in its most strenuous exertions and most glorious acts, and combining this view with the loftiest ideal aspirations of the greatest philosophers the land and the world have produced? What but this? that with regard to that institution, which has for its object to extend the bounds of human knowledge, we must realize the idea in the same manner as we endeavour to realize other ideas in our practice;—that what in a perfect monarchy would be done by a wise sovereign, we must do by voluntary exertion;—that in the place of a Solomon's House supported by the State, we must have a British Association supported by ourselves.

The British Association has now for ten years discharged the office of such an institution as we have spoken of. Considerable funds, raised by the contributions of its members, and expended under its direction, have been employed in furthering and verifying discoveries. It is true that we have not attempted to erect such edifices, and to make such preparations for the purposes of experiment, as Bacon introduces into his picture; but we have attained the same end more effectually, by procuring the use of many of the great establishments of manufacture and commerce which this empire possesses. We have had experiments carried on at furnaces and iron-works, on railroads and canals, in mines and harbours, with steam-engines and steam vessels, upon a scale which no institution, however great, could hope to reach; but which has been placed in our power by the enlightened liberality and scientific zeal of the proprietors and directors of such means of research. We have not had various bodies of professors of the art of discovery employed in these inquiries—we have not attempted to form classes of mystery men and dowry men—collectors of facts and interpreters of nature;—but we have found the most gifted and eminent cultivators of science in our own country, and several of those of other countries, ready and willing to undertake for us the office of exploring and interpreting nature—of extending and applying art. No institution, however formed, could have hoped to collect, as its active members, such a body of philosophers as have gladly come forward to labour for us, and have freely given us the resources of their vast powers and matured skill. Mathematicians, and astronomers, and geologists, and chemists, and naturalists, illustrious through Europe, have superintended the execution of our commissions with as much care as their own most favorite researches; and we have seen a co-operation of experimenters and calculators, observers and generalizers, such as might satisfy the wishes of Bacon himself.

That I may not dwell on mere generalities, I will mention a few of the sums expended by the Association upon scientific researches; which, when it is understood that they have been spent under the direction and vigilant control of such men as I have spoken of, will show the amount of service which has been rendered to science by that body. In the first three years, the sums thus expended were small, the Association having been mainly employed in collecting information which might direct its future proceedings. In the fourth year 167*l.* was thus spent, and from this time the sum went on rapidly increasing. In the fifth year it was nearly 500*l.*; in the sixth and seventh nearly 1000*l.* each year; in the eighth and ninth above 1500*l.* each year; and it appears that during the past year we have expended in this manner the sum of 1240*l.* And these sums, it is to be observed, are only a part of what were voted; at Liverpool, in 1837, above 3000*l.* was voted, of which 1000*l.* only was applied for; at Newcastle 3700*l.* was voted, and 1600*l.* of this only paid; at Birmingham 2800*l.* was voted, and 1500*l.* paid; the sum voted at Glasgow last year was 2600*l.*, of which, as I have said, your Treasurer has really paid 1240*l.*

These differences of the sums voted and paid in each year are evidence of the care with which the resources of the Association are husbanded; for the sums voted were to be had on application made by the persons to whom their disposal was intrusted; but they were not applied for, except in proportion to the scientific work which was done; and those who undertook these labours for us carefully confined their expenditure within the narrowest possible limits. It would occupy you too long if I were to mention in detail the subjects to which these sums have been applied; but I may state in general, that above 900*l.* has been expended by us in the furtherance of astronomy, mainly upon the object of reducing observations already made, into such a form that they can be directly compared with the theory. Above 800*l*. has been expended on tide observations; 250*l*. on experiments on waves; 500*l*. on experiments on the best form of vessels; 200*l*. on experiments on cast iron; about 400*l*. has been employed in various labours relative to meteorology; and above 300*l*. on the description of fossil fishes and reptiles. I shall not detain you by mentioning smaller sums which have been devoted to various objects; but I may call to your notice a work executed mainly in this county, upon which the Association expended about 550*l* in 1838 and 1839. This work consisted in striking a level line from the north coast of Somersetshire to Axmouth, in order to determine whether the level of the sea is the same in the Bristol Channel and in the British Channel, and in order to afford a standard of reference in future times, if, from any cause, the relative level of the land and the sea should change. This operation has already afforded us the means of determining, that the great land slip, which has recently taken place near Axmouth, was not accompanied by any permanent change in the level of the land itself, where a block of granite lies, which marks one of the extremities of our level line.

Since the first institution of the Association, about 7000*l*. has been expended on such objects as I have pointed out: but it is impossible for any one, who knows the nature of scientific researches, and the difference between the result of money expended in experiments by a good and a bad philosopher, to doubt that this sum has produced effects which many times the sum applied without the same advantages could not have obtained. Without the encouragement of the Association, these researches would never have been undertaken; without the aid of such men as have frequented the meetings of the Association, they would have been attempted to no purpose. It has been said of certain parts of Europe that they afford—

> Iron and man, the soldier and his sword;

in like manner we may say of this Association, that it has supplied at the same time the philosophical soldier and the weapons with which he gains his victories over nature.

But further, besides the expenditure of its own funds, the Association has been the means of procuring the appropriation of very large sums to scientific purposes from the national resources. At the suggestion or request of this body, the reduction of the observations of the planets made at Greenwich from the time of Bradley has been completed; and the reduction of the observations of the moon has been begun. Up to the present time, about 2200*l*. has been expended in all. And by a letter from the Astronomer Royal, received since I came here, I am informed that, within a few weeks, the Government expressed great willingness to advance more money for this purpose; and Mr. Airy adds, that next Monday he is to have twelve calculators employed upon the work. We have applied to the Government for the extension of the Ordnance Survey into Scotland, and have received a favourable answer. We have tendered our advice that the Ordnance Survey of England shall in future be conducted on a larger scale in the mining and metalliferous districts, and this advice is already acted on in the northern counties of England, where the survey is now proceeding on a scale of six inches to a mile.

Above all, I must mention an undertaking, entered upon in pursuance of our repeated recommendations (a service which the philosophers of future ages will duly estimate),—the great Magnetical Survey of the terrestrial globe, by the combined operation of a naval expedition and fixed observatories in every quarter of the world, which is now carrying into effect;—a scientific work, this—far surpassing, in the scale of its means and in the completeness of its design, any ever yet attempted, and such as Bacon might have assigned to the sages of his New Atlantis, if he had, in imagination, extended their polity from the Atlantic to the Pacific, and from Pole to Pole.

We most gladly bear our testimony to the liberality and spirit with which Her Majesty's Government have accepted and acted upon our suggestions; nor is this testimony at all weakened by our claiming for distinguished members of our own the merit of having brought into view the importance of such an undertaking, laid before the English public the progress which the subject was making in other countries, planned the scheme of operations which our own exertions ought to follow, and animated the observers, by giving them the certainty that their observations will be well used and fully appreciated.

When we can point to these numerous and valuable direct results of our exertions, we cannot at all waver in our conviction, that those persons acted in the truest spirit of the age, and of the nation, who, eleven years ago, framed the design of a voluntary association for the advancement of science among the subjects of this empire; and that the hopes and expectations which such an institution might naturally exercise, have been fully verified by the course and progress, the labours and successes of the British Association.

I do not doubt that the present Meeting will continue to uphold the character of the Association, and will be inferior to none of the preceding in the value and interest of its proceedings. We are not yet likely to want for matter to labour upon. The collection of facts and the reduction of them by various calculations is still required to a vast extent, in order that our knowledge may make the next step of progress to which its path invites our hopes.

It is easy to point out vast fields of research, on which our resources and our energies may be applied with every prospect of a rapid increase of knowledge. For, in fact, how little has been done for science, by the collection of exact and long-continued series of observations, such as he must have before him who is to interpret nature! In astronomy, indeed, this has been done: sovereigns, and nations, and opulent individuals have thought their wealth well bestowed in providing costly instruments, and rewarding the astronomer through his daily and nightly toils. The stars have been well observed from the beginning of civilization; but, for the purposes of science, we ought to have observations as careful and as continued of all the other parts of nature as we have of the stars. The tides, the waves, the winds, and all the other changes of the air, pressure, temperature, moisture, magnetism, electricity, chemical changes, and even those of vegetable and animal life,—all these afford materials for researches full of importance and interest. For these, the time is, perhaps, not yet come, when they can be urged upon governments as a part of their business, in the same way in which astronomy is;—except, perhaps, magnetism, which has already taken its place in our observatories by the side of astronomy, in our own and other countries. Those other subjects, then, are fitly cultivated by a voluntary association such as ours; and the occasions of fitly doing this will doubtless be suggested to us from time to time by our members. On the present occasion, a distinguished Belgian philosopher, one of our corresponding members (M. Quetelet), comes to us to invite us to take a part in determining, by extensive observations, the changes which atmospheric conditions produce in periodical phænomena,—such as the times of the leafing and flowering of plants, of the arrival of birds, and the like. He has obtained extensive co-operation in his own country, and no doubt will find fellow-labourers in ours. Meteorology, in its largest sense, is a subject which, although great collections of observations have been made, is hardly yet a science: yet the interpreters of this part of the book of nature have already begun to spell out some phrases, which show that the language is not wholly unintelligible; and here, therefore, we may go on hopefully, recollecting always that the collection of facts is a matter of comparatively small value, except we can also trace in them some rule or order. The mere gathering of raw facts may be compared to the gathering of the cotton from the tree. The separate filaments must be drawn into a connected thread, and the threads woven into an ample web, before it can form the drapery of science.

We ought to have meteorological observations and observers distributed over the face of the globe: and even this would not be enough; for we wish to know not only what passes on the earth's surface, but through the whole depth of the atmosphere; hence it would be desirable to have observations made at elevated points free from the action of the ground—such as can only be attained by the aid of balloons. Such an undertaking has been under the consideration of a committee during the past year, and a report on the subject has come before the Physical Section. I trust that on this subject you will soon hear more. As other subjects on which we still want facts—that is, numerous and systematical collections of facts, and laws deduced from facts—I may mention the tides of the Pacific, the velocity of sea waves, and subterraneous temperature. Another class of inquiries well fitted for our labours, is the determination of the fundamental elements, or *constants*, of operations of engineering, as the constants of railroads, steam-engines, and other works of art, which form part of the wealth and resources of this great empire. These are already under investigation. The addition of a Section of Practical Mechanics and Engineering to the previous constitution of the Association, which took place at Bristol, showed the interest which such inquiries inspire; and various committees have collected much valuable information of this kind, and will, we trust, collect much more.

There is also another Section of the Association, added to its plan at Cambridge, which has for its object researches of a highly interesting kind,—I mean the Section of Statistics; and we trust that there is ample employment for this Section, in subjects which can be dealt with in the same calm speculative spirit as the other sciences which we here cultivate.

It may, perhaps, sometimes be useful to us to recollect that in many statistical subjects, the discussion, and even the collection of facts, is rather the office of a legislative than of a scientific body. The wise institutions of Bacon's New Atlantis would have assigned to the governors of the land, and not to the sages of Solomon's House, the collection of information respecting the habits, numbers, and education of the people, where the information is such as almost necessarily suggests legislation, or discussions having legislation for their natural end, and involving the deepest political and moral considerations. There may very fitly be voluntary associations, which aim directly at improving the intellectual, or moral, or social condition of our population; but we must ever remember that we are an association for a different purpose, namely, the advancement of science; and we are bound alike by our regard to the prosperity of our body, and by our most solemn and repeated declarations, to avoid the storm of opinions which is always raised when the parties which aim at social permanence and social progress are brought into conflict. The pursuit of scientific truth is, no doubt, a means of *indirectly* elevating man's intellectual and social condition; but we assemble in order to promote the *direct* pursuit of scientific truth; and we must not turn aside into the more wide and tangled paths of those who make its collateral effects their main object. Knowledge is power, we are told, Knowledge *is* power; but for us, it is to be dealt with as the power of interpreting nature and using her forces; not as the power of exciting the feelings of mankind, and providing remedies for social evils, on matters where the wisest men have doubted and differed.

Being the person whose voice is first raised in addressing the meeting of the Association, I have thought that it was a part of my duty to use the opportunity in calling to our minds the fundamental character and principles of our institution. There are other subjects which our constitution directs us to avoid; but none perhaps in which there is much danger or need of warning. We are in no great risk of deviating into literary, or metaphysical, or theological discussions. Sound metaphysics and literary culture will of course show themselves in the addresses of those who possess such accomplishments, but are no direct objects of our attention. And in like manner, though we cannot dream of the slightest approach to the discussion of religious questions, heartfelt and real piety may be apparent even in the sentiments uttered at an association for the advancement of science. I am sure that many of you who attended the former meetings of this Association, must recollect occasions on which men's minds being excited, and yet solemnized, by the aspect of the assembled multitudes, and by the lofty views of nature which our philosophers had to present to them, the thoughtful and eloquent men who had to address you were carried by a spontaneous impulse, without plan or premeditation, into elevated strains of religious reflection; showing that those who take the lead in our meetings have their minds so tuned, that every voice which proclaims the wonders of nature, turns their thoughts to the Author of nature; that every new gleam of truth seems to them an effluence from the eternal fountain of truth. Long may such habits of thought prevail among the philosophers of this land; and then we need not fear but that knowledge, hallowed and elevated by the spirit in which it is pursued, will be every way a blessing to man,—to his soul as well as to his body—to his spiritual as well as to his intellectual being.

To those of us who, knowing the institution by our attendance upon it, and our share in its labours, think thus of its value and its spirit, every new annual occasion of our coming together must be an occasion of fresh gratification, an agreeable exercise of memory and of hope. In our present meeting at this place, there are many circumstances to give additional animation to our anticipations of pleasure. We come to a part of the empire hitherto unvisited by many of us, to a great maritime town, replete with objects of instruction, art, and interest. We know the love of science and the familiarity with its treasures which here prevail, for we are acquainted with the high character, the knowledge, zeal, and ability of the authorities of the Dockyard—the intelligence and activity of the Plymouth Institution,—we know and feel most gratefully, the kind and vigilant care with which preparations have been made for our reception; and we now see in this assembly, the look of cordial welcome and lively anticipation, of which I would say more, but that I would beg to leave the subject in abler hands. We hail with joy and confidence the opening of the Plymouth Meeting of the British Association.

Perhaps you will allow me the gratification of saying a word respecting special personal reasons of my own, which make it a matter of pleasure to me to find myself here on this occasion. Besides that it brings me to the society of several valued and cherished friends, whose home is in this part of England, I have various ties of a scientific nature with this place and this region. The excellent observations of the tides made in this harbour, have been the subject of calculations involving considerable labours, which I have made or directed: and some curious traits in the laws of tidal phænomena here, which were noticed as early as the time of Newton, have, I trust, been followed out to a tolerably exact determination. An anemometer, which I had devised, has been erected here, with most valuable improvements, by Mr. Snow Harris, and has been for some time in operation. And when I consider, as we may do, this meeting as a meeting peculiarly intended to bring the Association in contact with the West of England, I find that Cornwall returns to my thoughts, with all the scientific zeal and intelligence, which from my own personal intercourse I know to exist among the miners of that county. Perhaps I have had very unusual opportunities of becoming acquainted with their merits, for in two different years (1826 and 1828), in the prosecution of certain subterraneous experiments, undertaken in conjunction with the present Astronomer Royal and other persons, I lived four months the life of a labouring miner, and learnt how admirable for skill and conduct is the character of all classes of the mining population in that region. If any of my Cornish friends are within hearing, I gladly bid them God speed, and claim once more their welcome to the West. And that I may no longer detain you, to all of you, gentlemen of the British Association, I bid God speed; and from all of you, gentlemen of Plymouth and its neighbourhood, I seem to hear, Welcome to Plymouth!

REPORTS

ON

THE STATE OF SCIENCE.

On the Present State of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat. By the Rev. PHILIP KELLAND, *M.A., F.R.SS. Lond. and Edin., Prof. of Math. in the University of Edinburgh, late Fellow of Queen's College, Cambridge.*

THE object of the following report is simply to lay before the Association an outline of the present state of our theoretical knowledge of the law of transmission of heat by conduction, and to examine how far conclusions deduced from theory have been tested by experiment. Reports on the general problem of Radiant Heat have already appeared by Professor Powell*; and on the theoretical laws of conduction and radiation, a portion of the subject-matter of our present question, Mr. Whewell has briefly touched in his report 'On Magnetism, Electricity, Heat, &c.†' We shall, in consequence, confine ourselves strictly to our immediate limits, noticing only such other branches of the general theory as bear directly or necessarily on the question. We shall avoid all mention of theoretical investigations, however important in themselves, which are not capable of being examined rigidly by direct experiment; nor shall we scruple to pass over the names of a host of illustrious experimenters on conduction and radiation, when we find that their experiments are not calculated to serve as the immediate test of theory. This proceeding will materially shorten our labour, and will have the effect of condensing into a narrow compass all the remarks we have to make.

To render what has to be said as clear as possible, the subject-matter has been arranged under three heads. Two of these are distinctly marked out by the statement of the object proposed to be effected, and the third is suggested by a consideration of the former two.

We shall examine, then, I. What is the present state of our theoretical knowledge of the phænomena of conduction. We are here to seek for the principles on which the reasoning is based, to inquire what are the *axioms* of radiation and conduction, or of the flow of heat, which, from observation, experiment or analogy, have been assumed to hold true, and to point out the conclusions to which these axioms have led. We have to distinguish between differing theories, and to contrast with each other some of the most simple of the results to which they respectively lead. This portion of our subject must, to a certain extent, be treated historically.

We shall inquire, II. into the state of experimental investigation, so far as it has been undertaken with a view to test or to illustrate the conclusions arrived at by theory. We shall examine how the different consequences of certain hypotheses bear the test thus applied to them, by computing from the formulæ the values of the temperature corresponding with the conditions existing in the experiment, and contrasting the results with the temperatures actually observed. This critical discussion of the hypotheses will lead us in the third place

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* Report on Radiant Heat in Reports of British Association, vols. i. and ix.

† Reports of the British Association, vol. iv.

To point out, III. the utter inadequacy of the few experimental facts with which we are furnished, to serve either as the basis of a true theory or as the indication of a false one. We admit that, of a theory based on assumptions which have been for a century regarded as only approximative to truth, the experiments are sufficient to expose the incompetency, just as experiments on bodies sliding under the retardation of friction will easily detect the inadequacy of formulæ deduced from the hypothesis of absolute smoothness. But we shall see that, as applicable to point out errors in the assumed axioms on which reasonings are founded to constitute a physical theory, the experiments we possess are defective both in their number and in their nature. We shall find three distinct theories equally verified or equally overturned by them, according as we choose to regard the conclusions as indicating the one or the other; and yet we are quite sure that *only* one of the theories is the correct one, whilst on the other hand we can hardly entertain a doubt that *one* of them is so. When we shall have made this appear, it will only remain for us to point out, in conclusion, what are the most important results of theory which it is desirable that experiment should be brought in to test, and to suggest a few of the most simple means of effecting the object desired.

I. The problem, in the solution of which consists the mathematical theory of heat, is the following. *Having given the state of heating, or the variation of that state from time to time, at one or more points of a homogeneous body of given form and dimensions, to find the permanent or variable temperature at every other point.* Thus a ring is kept at a certain temperature at one point, and it is proposed to discover, 1. what is the variation from time to time of the temperature at every other point, and 2. what is the ultimate temperature to which that at any given point approaches as the time during which the constant heating of one point has been kept up is increased.

From this statement it will appear that the experimental facts on which the theory must rest are the answers to the following questions. *a.* According to what law does a heated body lose its temperature to the air, or other medium or space, by which it is surrounded? *b.* According to what law is temperature transmitted from point to point of a body? On the correctness of the answers which may be assumed as given to these questions depends the applicability of the results obtained to the state of things in nature. But as in mechanics we may reason correctly on assumed laws which are not laws of nature, and obtain conclusions of great importance as approximations to facts, so in the theory of heat the results, although *strictly* commensurate only with the laws on which they depend, are still highly important even in reference to the things actually existing, differing as they do in certain cases from the expression of the laws.

We proceed then to show what answers have been given to the above questions by different theorists, and to explain the evidence on which their truth is supposed to be established.

a. *Radiation.* Sir Isaac Newton appears to have been the first who was led to apply a law of radiation to experiment. The statement of the law is given by him for the first time in a paper in the Philosophical Transactions for 1701 *, and is reprinted in his Opuscula †.

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* Philosophical Transactions, 1701, vol. xxii. p. 827.

† Newton's Opuscula, vol. ii. p. 422.

Newton's law of cooling.—The author is constructing a scale of temperatures; he is comparing, for instance, the heat of boiling water with that of the human body. The comparison is made immediately, to the extent to which the thermometer affords an indication of the temperature; beyond this it is requisite to have recourse to some process which involves computation; and to this end Newton admits the hypothesis, to which we apply the designation given above. His words are as follows (translated): "This table was constructed by the use of a thermometer and red-hot iron. By means of a thermometer I found the measure of the heat up to the point at which tin (*stannum*) is melted, and by heated iron I found the measure of the rest. For the temperature which heated iron communicates to cold bodies contiguous to it, in a given time, is as the total temperature of the iron. Therefore, if the times of cooling are taken in arithmetical progression, the temperatures will be in geometrical progression, and may be found by a table of logarithms."

It is affirmed by most modern writers that Newton was *led* to this law by experiment. This was very probably the case, for to the extent of temperature indicated by his thermometer it would be very nearly verified.

The inaccuracy of this law was first pointed out by Martine*. He found, that although it appears very exact when the temperature of the heated body does not differ much from that of the surrounding air, yet when the temperatures differ considerably it is very far from being the case. Erxleben † also proved that the law is at fault in *proportion* to the excess of the temperature of the body. Mr. Dalton ‡, in his 'New System of Chemical Philosophy,' in a truly philosophical manner attempted to re-establish the law of Newton by altering the thermometric scale. The hypothesis on which he bases his views is, that the dilatation of all liquids is subject to the same law. MM. Dulong and Petit conceive that Dalton's views are untenable, arguing that, "even supposing the accuracy of the principles of this new scale to have been proved, we should be constrained to acknowledge that it does not satisfy the condition of rendering the losses of heat of a body proportional to the excess of its temperature above that of the air which surrounds it, or, in other words, that it does not re-establish the law of Richmann §; for it would be necessary in that case that the law of cooling should be the same for all bodies, and our experiments rigorously prove the contrary ||."

We presume MM. Dulong and Petit's argument to be based, not, as would appear from the phrase quoted, on the variability of the *law* of cooling, so much as on the fact that for different substances the two portions whose sum, according to these authors, constitutes the law, are affected with very different multipliers, so that their relative values depend altogether on the nature of the body. To this matter we shall return in the sequel ¶.

M. de la Roche of Geneva ** likewise pointed out the deviation from Newton's law, at the same time admitting that it is sufficiently accurate to 212° Fahr., which is perhaps rather more than subsequent discoveries warrant us in assuming.

We come now to the time when the law was established in its correct form, so far as we can see at present. The whole merit of the discovery is due to

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* Martine, Essays on Heat, 1740, p. 236, art. 4.

† Novi Commentarii, Soc. Gott., vol. viii. p. 74.

‡ New System of Chemical Philosophy, 1808, p. 12.

§ Kraft and Richmann, Novi Commentarii, Petrop. i. p. 195.

|| Dulong and Petit, Journal de l'Ecole Polytechnique, 1820, tom. xi. p. 237.

¶ Consult their Memoir, p. 190.

** Journal de Physique, 1812, tom. lxxv. p. 201, Prop. 6. Annals of Philosophy, vol. ii. p. 100.

MM. Dulong and Petit, to whom the Academy of Sciences awarded the prize in 1818, and whose admirable memoir 'On the Measure of Temperature and the Laws of Communication of Heat' the reader will do well to consult*. All that we can do is to give a very brief outline of their researches. The first step requisite for them to take was the determination of a correct measure of temperature. To present to the eye an indication of the state of heat of a body the principle of dilatation has been most commonly applied, but it becomes a question to ascertain what substance will by its dilatation express the state of heat the most simply. MM. Dulong and Petit, having determined "that all the gases dilate absolutely in the same manner and by the same quantity for the same change of temperature," conclude that the air-thermometer is the best indicator of the state of heat. They argue, "that the well-known uniformity in the principal physical properties of all the gases, and particularly the perfect identity of the laws of their dilatation, renders it very probable that in this class of bodies the disturbing causes have not the same influence as in solids and liquids, and that, consequently, the changes in volume produced by the action of heat upon them are more immediately dependent on the force which produces them. It is therefore probable (they think) that the greater number of the phænomena relating to heat will present themselves under a more simple form if we measure the temperatures on the air-thermometer. It is at least by these considerations (they inform us) that we have been determined constantly to employ this scale†." Having thus settled that the air-thermometer is to be taken as the measure of temperature, they proceeded in the next place to obtain the laws of cooling *in vacuo*. And here we cannot but express our regret that the original unreduced observations of the authors are not presented to the world in some work generally known. We have never seen them, nor are we sure that they have been published at all. We take the present opportunity of further expressing our astonishment that experiments on which so much depends have never been repeated in this country. We do not know any more desirable exercise of the funds and energies of public scientific bodies than the repetition of all experiments, and the institution of others in a trying form, on which laws of nature have been partially or totally founded. In the case before us we do not doubt the accuracy or fidelity of the ingenious experiments, but we wish to be assured by cumulative evidence that the *constant* introduced into their law is determined with sufficient accuracy. To return from this digression.

The velocity of cooling was experimented on by our authors by means of heated thermometers placed in a balloon nearly free from air; but the observations were subjected to two corrections. In the first place the stem of the thermometer without the balloon soon becomes cooled down to the temperature of the surrounding air. Every temperature observed therefore was too low by a number of degrees equal to that to which the mercury in the stem would dilate, when heated from the temperature of the surrounding atmosphere to that of the bulb. A correction on this account was applied to all the temperatures observed. The second correction was destined to reduce the observations actually made on the mercurial thermometer to the corresponding indications of the air-thermometer. Besides these corrections, rendered requisite by the nature of the experiments, there was a third which arose out of the necessary imperfection of the vacuum. This was applied to the resulting velocities, and its value was ascertained by making corresponding experiments on vacuums of different degrees of imperfection, and thence computing the amount of error introduced by the action of a known quantity of air.

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* Annales de Chimie, tom. vii. p. 225, &c. Thomson's Annals of Philosophy, vol. xiii. p. 113, &c. Journal de l'Ecole Polytechnique, 1820, tom. xi. p. 189.

† Journal de l'Ecole Polytechnique, tom. xi. p. 232.

The result to which our authors arrived is expressed by the following law. "When a body cools *in vacuo*, surrounded by a medium whose temperature is constant, the velocity of cooling for excesses of temperature in arithmetical progression increases as the terms of a geometrical progression, diminished by a constant quantity." The formula which expresses the velocity of cooling is $m\,a^{\theta}\,(a^{\delta}-1)$, where a is the same for all bodies, viz. 1·0077 or $\sqrt[20]{1\cdot165}$, θ denotes the temperature (marked by the air-thermometer and measured on the centigrade scale) of the vacuum in which the cooling body is placed, and δ the excess of the temperature of the body above θ.

On cooling in air or in gases.—The hypothesis on which was computed the velocity of cooling in air or any other gas, was, that the velocity might be divided into two parts;—the one, that due to direct radiation *in vacuo*; the other, that due to the actual presence of the gas. The gas was supposed not to influence directly the process of radiation, but to act in aid of it by conduction or convection, or a combination of both. Proceeding thus, MM. Dulong and Petit first verified the observation of Leslie, "that the loss of heat owing to the contact of a gas is independent of the state of the surface of the body which cools." They showed next, "that the velocity of cooling of a body, owing to the sole contact of a gas, depends for the same excess of temperature on the density and temperature of the gas; but this dependence is such that *the velocity of cooling remains the same so long as the elasticity is unaltered*." They found also, "that the cooling power of a gas is, *cæteris paribus*, proportional to a certain power of its elasticity, but that the index of the power varies for different gases;" and moreover, "that the velocities of cooling due to a gas increase in geometrical progression as the excesses of temperature increase in geometrical progression."

We shall best understand the whole law of cooling by exhibiting it in the shape of a single formula. It is as follows:

$V = m\,.\,1\cdot0077^{\theta}\,(1\cdot0077^{\delta}-1) + n\,e^{p}\,\delta^{1\cdot233}$, where m depends on the nature of the surface, and n and p on the nature of the gas. θ is, as before, the temperature of the gas, and $\theta+\delta$ that of the cooling body; e, the elasticity of the gas.

If this be the law of nature, we can hardly term by the same word *radiation* the loss of heat *in vacuo*, and the loss due to the action of the surrounding air. We must therefore, for the present, confine our signification of this term to the former, and admit that results deduced from the hypothesis of radiation apply only to experiments carried on in a space free from air.

b. *Conduction.* Ordinary experience teaches us that the power of conduction differs in different substances; and it is natural to suppose, and has, in fact, been universally admitted, that this difference is a difference in *intensity* only. It is *assumed* that one and the same law holds good for all bodies, but that a certain factor, on which the absolute amount of conduction depends, differs according to the nature of the substance. But to define the *law* of conduction, which is the same for all substances, considerable difficulty has been experienced. Lambert*, and the other early writers on the subject, regarded the flow of heat as the flow of a fluid. But when we treat the subject mathematically, and regard the flow of heat as the flow of an elastic fluid, considerable difficulties present themselves. We do not know that the difficulties are real; we think, as Mr. Whewell hints[*], that they are introduced by an arbitrary assumption concerning infinitesimal magnitudes. One difficulty is as follows: If heat flow from one point or place to another, the variation of temperature is a quantity of the first order; whilst if we obtain the variation by estimating the gain and loss of heat which that point or plane receives, we shall find it to be a quantity of the second order. Biot, who in 1804 read to the Institute a short memoir on this subject[†], was constrained to leave his fundamental equation without demonstration on this account[‡]. The difficulty is supposed to have been removed by Laplace[§], who does indeed present reasoning bearing with some weight on the subject. But we could have wished that he had distinctly answered the following question. If three equal, small, contiguous slices of a bar be conceived collected each at its middle plane, will the quantity of heat which in a given time passes from the first to the second, or from the second to the third, depend on the (small) thickness of the slices or not? Fourier doubtless saw that it would not, and therefore, instead of reasoning on the difference of heat between two portions of the body directly, he fixes his attention on the *flow* of heat across a plane. His reasoning is as follows:—A homogeneous body is supposed to be traversed by two parallel planes whose distance is e, of the lower of which every point has the same temperature a, and of the upper a different and less temperature b. Then, if v represent the temperature at any intermediate point at the distance z from the lower plane, the expression $v = a - \frac{a-b}{e} z$ being supposed to be once established as the law of the temperature at all points, no change will take place in the state of heat of the body[||]. To prove this he takes two points at equal distances from the plane whose temperature is v, the one above, the other below it, and shows that the excess of the temperature of the lower above v is exactly equal to the defect of temperature of the upper from v. He then concludes thus: "It follows that the quantity of heat transmitted by the lower point to the middle one is the same as that which the middle one transmits to the upper, *for all the elements which concur to determine this quantity of transmitted heat are the same*[¶]." Thus M. Fourier's hypothesis of conduction is, that *the flow of heat depends on the difference of temperature*; or as he gives it, "the flow of heat across a given plane, whose distance from some fixed plane is a and temperature v, is proportional to $\frac{dv}{dx}$." This we regard as the first law of conduction.

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* Act. Helvet., vol. ii. p. 172.

No doubt M. Fourier has confounded heat with temperature; but this confusion is merely a confusion of terms; the reasonings and results are unaffected by it.

M. Poisson, founding his theory on molecular interchange, and having in view Dulong and Petit's law of radiation, admits another law of conduction. This law is thus expressed: "The change of heat between two points depends on the product of the difference of temperatures of those points, and of a function of their positions and temperatures[**]." In M. Poisson's earlier investigations the latter factor had been regarded as a function of the *positions* of the particles only*; although he was led by analogy to the adoption of the above law, as he himself informs us †, yet he does not appear to have adopted the *law* of Dulong and Petit itself as the law of conduction. He leaves it indeterminate, having found, as we shall show in another part of our report, difficulties in admitting such to be the case.

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[*] History of the Inductive Sciences, vol. ii. p. 470.

[†] It is printed in the Bibliothèque Britannique.

[‡] See Biot, Traité de Physique, tom. iv. p. 669.

[§] Laplace, Mémoires de l'Académie, 1809, p. 332. Connaissance des Tems, 1823, and Mécanique Céleste, liv. ii.

[||] Fourier, Théorie de la Chaleur, p. 47.

[¶] Ibid, p. 49.

[**] Poisson, Théorie de la Chaleur, art. 48.

Lastly, the author of the present report, in a short memoir which he read to the Royal Society of Edinburgh ‡, suggested the possibility of the existence of a third law of conduction, differing considerably from either of the former as they are actually adopted, but which might be made to differ little from Poisson's by the change of a few of the quantities to which that author has assigned values. The law may be stated briefly as follows:—"The flow of a function of thermometric temperature across a given plane varies as the difference of the values of this function on the two sides of the plane." It will be seen at once that this law restores us all Fourier's conclusions, provided we regard his phrase "heat" or "temperature," which he uses indifferently, as signifying a *given function of thermometric temperature*. These are the only laws of conduction which have been suggested: they are mere hypotheses. In seeking for a law of radiation we may have recourse to direct experiment, but here no such means are in our power. All that we can do is to experiment on the combined effects of radiation and conduction; and then, supposing ourselves in possession of the effects due to the former, to eliminate them, and infer the law of conduction from the remainder. But this cannot be done without computation, and computation cannot be effected without formulæ, which latter must be based on the hypothesis of conduction itself. Thus we are reduced to the indirect method of assuming the law, and testing by experiment the conclusions which spring from the assumption. We must prepare, therefore, to examine the results of analytical investigation applied to certain laws of radiation and conduction which are at first conceived to be true, but only to be finally established by the conclusions themselves. Before we proceed, it will, perhaps, be as well to repeat that we have found two laws of radiation and three of conduction to exist as the assumed laws of nature. By the combinations of these laws we could conceive six different theories of heat to arise. Of these two would be obviously at variance with our present notions of fact; the other four have to be examined.

All the earlier theorists assumed, as we have already stated, the most simple axioms of radiation and conduction, viz. that the flow of temperature is proportional to the excess of temperature. Such being the case, we may venture to pass over the labours of Biot, Laplace, and others, not because they are unimportant, but because the same results are to be found in the more extensive and systematic writings of Fourier. In 1807 this philosopher read before the Institute a memoir, in which the subject was treated in a masterly manner, and the difficulties which had previously encompassed it were removed §. The Academy of Sciences, with the laudable design of inducing the author to prosecute his researches, proposed as the subject of the Prize Essay to be awarded in 1812, "To give the Mathematical Laws of Radiation and Conduction, and to establish them by experiment." Accordingly, on Sept. 28, 1811, M. Fourier's second memoir was deposited in the archives of the Institute. The prize was decided to have been gained by it, but not without an expression of the restrictions which the Academy put on its favourable opinion. The committee appointed to examine and report on the memoir, consisting of Laplace, Lagrange and Legendre, whilst they agreed in proclaiming the novelty and importance of the subject, and in declaring that the equations are the true equations required by the conditions, expressed a difficulty about the way in which they had been deduced, and added, that the means employed to effect their integration left much to be desired. Fourier never yielded to this judgment; and accordingly he printed his memoir exactly as it was written in the memoirs of the Academy for 1825 and 1826: nor did he ever modify or extend his views, so far as we know. He published his Treatise on Heat in 1822, which does not essentially differ from his memoir.

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* Journal de l'Ecole Polytechnique, tom. xii. p. 87.

† Théorie de la Chaleur, Preface, p. 6.

‡ Proceedings of the Royal Society of Edinburgh, Dec. 16, 1839, p. 279.

§ Bulletin des Sciences, 1808, tom. i. p. 112.

It is not necessary to trace all the circumstances which withheld from the world these important investigations for so many years. We must not lay all the blame on the Institute; doubtless a part of it falls on Fourier himself. The accounts which had appeared were scanty. They will be found in the 'Annales de Chimie,' iii. 250 (1816), iv. 128 (1817), vi. 259 (1817); 'Bulletin des Sciences de la Société Philomatique', 1818, p. 1, and 1820, p. 60; the 'Analyse des Trauvaux de l'Académie,' 1820, &c. by Delambre.

Whilst the memoir lay in the archives of the Institute, the labours of Dulong and Petit had, by the establishment of another *law*, rendered it desirable that the theorist should reconstruct his equations and extend his analysis. We can understand well enough why M. Fourier did not attempt this. Whilst his own investigations lay unknown, he had no inducement to extend or continue them: far less was he likely to take in hand a totally new investigation which could hardly be expected to present results so beautiful and symmetrical, and must, from their further approach to a correspondency with the laws of nature, have withdrawn attention from his previous labours. But we are astonished that M. Poisson, who laboured successfully in this as in every other field of mathematical physics, did not see the necessity of adopting axioms conformable to fact. We suspect that he and Lamé, and all the other writers who treated of the subject, were more anxious to pursue a line of investigation which led to symmetric formulæ, than one which should lead to results conformable with the facts of experiment.

The person who first attempted an investigation based on principles more approaching to the probable law of nature was M. Libri. His memoir was read to the Academy of Sciences in 1825, and is printed in the 'Mémoires de Mathématique et de Physique'*, and in 'Crelle's Journal' for 1831, vii. 116.

The grounds of his investigations are, 1. That extra-radiation follows the law of Dulong and Petit. 2. That conduction follows the law of Biot, Laplace and Fourier. He confines himself to the solution of one problem, as the most simple that could be selected to illustrate his views. The problem is the determination of the temperature of a ring heated at one point. The author integrates the equation for the variable state of heat on the hypothesis that the variation from the ordinary results which is introduced by taking Dulong and Petit's law is a small quantity. Certain peculiarities in his process of integration have drawn the attention of those who are interested in the subject to this memoir. The author of the present report was the first to find fault with M. Libri's solution in 1837†. Others have, since that time, joined in the opinion; amongst the rest M. Liouville. The paper of this author, read to the Institute, and published in his 'Journal des Mathématiques' for 1838, has caused some little discussion on the subject, which the reader will find in the 'Comptes Rendus' for 1838, 39 and 40.

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* Florence, 1829.

† Theory of Heat, p. 69.

We should not have thought it necessary to mention this subject were we not desirous of seeing the attention of philosophers directed to this branch of physics. It is extraordinary, that a theory, professing to be a physical theory based on experiment, should have been suffered to lie for twelve years hardly known in fact, but occasionally alluded to as complete and satisfactory. In the kindred science of optics half the time would have sufficed to attract the attention of the whole scientific world; and experiment and analytical investigation would have been lavished on the subject. We hope M. Libri will be induced to pursue his investigations further, and to reduce the results to a tangible form.

The next theory to be mentioned is that of Poisson. In his 'Théorie Mathématique de la Chaleur' (1835), he adopts the law established by Dulong and Petit for extra-radiation, and conceives that a similar law may apply to the interior transmission of heat. The hypothesis on which he proceeds relative to the changes of heat between all parts, the complication of his results, and a degree of uncertainty which hangs over the *law* of change, render his work rather a display of analytical artifice than an attempt to build up a theory by applying to it the test of an examination by contrast with the facts it is designed to account for. It is to be regretted that M. Poisson, in turning his attention to the fundamental difficulties in the theory, did not adopt the plan of endeavouring, in the first place, to remove them, and afterwards to advance to the application of the same principles to the more difficult and complex questions which might present themselves. As it is, we can find in his work only one conclusion to which we can turn, in the present state of our knowledge, with the view of applying to it the test of experimental examination: this result we shall exhibit in its proper place. We have only to add, that M. Poisson's equation has been deduced by Mr. Rankine in the 'Edinburgh Academic Annual,' and applied to the determination of the temperature of a heated globe.

Lastly, the author of the present report has suggested that it is proper to try a fourth theory, the last which the combinations of the laws of radiation and conduction admit of. It does not appear improbable, that although the flow of temperature does not depend on the difference of temperature, the flow of heat should depend on the difference of heat, provided we regard heat as a certain state of the body different from temperature. This theory then rests on the hypotheses, 1. That the variation of v due to cooling *in vacuo* depends directly on v. 2. That the flow of v across a given plane varies as the difference of the values of v on the two sides of that plane.

Thus this theory coincides altogether with Fourier's, except that v is no longer the temperature, but a certain function of the temperature. The function appears to be $v = A\,(1 - a^{-\theta}) + B$*, where θ is the temperature and a is Dulong and Petit's constant.

These are the four theories which at present exist, each based on the combination of one of the two axioms of radiation with one of the three axioms of conduction. We propose now to write down some of the most important and simple of the conclusions to which they respectively lead.

I. *Fourier's hypothesis.* That the flow of temperature depends directly on the difference of temperature, both within and at the surface of a body. As we have already stated that one of the formulæ had been given by Biot prior to the appearance of Fourier's memoir, it will save confusion, if, notwithstanding, we make our references to Fourier's work alone.

Formula 1.—The permanent temperature of an infinite homogeneous solid, bounded by two parallel planes, each of which is, and has been, for an indefinite time, kept at the same uniform temperature throughout, represented for the one plane by a and for the other by b, is expressed by the following equation: $v = a + \frac{b-a}{e} z$; where v is the temperature at the distance z from that plane whose temperature is a, and e is the distance between the planes. (Fourier, Théorie de la Chaleur, Art. 65.)

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* Athenæum for October 24, 1840, and Report of British Association for 1840.

2. A very small square prismatic bar is kept heated at one end until the different parts of the bar have acquired a permanent temperature. That temperature, or rather, as it actually is, the excess of temperature above that of the surrounding medium, is represented by the equation,

$$v = \mathrm{A}\, e^{-x\sqrt{\frac{2h}{kl}}} + \mathrm{B}\, e^{x\sqrt{\frac{2h}{kl}}};$$

where x is the distance of the point whose temperature is v from the heated extremity of the bar, l is a side of the section, and h and k the coefficients of radiation and conductivity of the bar.

Cor. If the bar be supposed very long, B must be equal to 0, and $v = \mathrm{A}\, e^{-x\sqrt{\frac{2h}{kl}}}$.

Here A represents the heat of the extremity, and $\sqrt{\frac{2h}{kl}}$ is a quantity which must simply be determined by experiment. (Art. 76.)

3. The permanent state of temperature of a ring is represented by $v = \mathrm{A}\, a^{-x} + \mathrm{B}\, a^{x}$, where x is the distance of the point under consideration from some fixed point, measured along the arc which passes through the centre of the generating circle. (Art. 106.)

Cor. If points be taken at equal distances along the axis of the ring, the ratio of the sum of the temperatures of the first and third to the temperature of the second, is the same, whichever point be taken first. (Art. 107.)

4. The temperature at any point of a ring which has been heated at one point to a stationary temperature, and is then suffered to cool, is represented by $v = 2\, e^{-ht}\, \mathrm{M} \left\{ \frac{1}{2} - \frac{\cos x\, e^{-kt}}{1^2+1} + \frac{\cos 2x\, e^{-2^2 kt}}{2^2+1} - \frac{\cos 3x\, e^{-3^2 kt}}{3^2+1} + \&c. \right\}$ (Art. 242.)

5. As the time increases, the law of temperatures in a ring tends to become such that the sum of the temperatures at the opposite extremities of a diameter is equal to $2\, a^{-ht}$; which shows that the sum is the same at the extremities of whatever diameter we estimate them. (Art. 245.)

II. *Libri's hypothesis.* That the interior conduction follows Newton's, and the extra-radiation Dulong and Petit's law. The author has only applied his analysis to the motion of heat in a ring. The conclusion to which he arrives is the following:

6. If a ring be heated at one point and then left to cool, the sum of the temperatures at a given instant at the two extremities of a diameter is the same for every diameter that may be taken.

This result, which is only approximate, is not adapted for testing the truth of the theory. It is, however, quite independent of any considerations respecting the mode by which the equations may be integrated.

The author of the present report has applied Libri's hypothesis and method to the solution of the same problem. He finds that

7. The effect of Dulong's law is, that the velocity of cooling diminishes

more rapidly than it would if Newton's law were true. Nothing else is altered. (Theory of Heat, p. 75.)

This result, it must be confessed, is deduced from the omission of many terms in the equation in order to effect an approximation. It can hardly be regarded as a tolerable expression of fact.

III. *M. Poisson's hypothesis.* That extra-radiation follows Dulong and Petit's law, whilst conduction follows an analogous law,—the flow of temperature depending on the product of the variation of temperature, and a function of the temperature. In M. Poisson's large work will be found the solution of a considerable number of the resulting equations; but the solution is in general approximate, and effected in such a manner as to reduce the hypothesis actually to M. Fourier's hypothesis. We find very few practicable results in the work, derived from the proper axioms on which it professes to be founded. One only can be given which will serve the purpose we have in view. The equation which gives the permanent state of heat in an uniform prismatic bar is $\frac{d}{dx}\left(k\frac{dv}{dx}\right) = \frac{e}{\omega}\,p\,(v-\zeta)$; (Art. 118.) where k and p are functions of the temperature, such that $k\,\frac{dv}{dx}$ and $p\,v$ respectively represent the flow of heat in a small time (considered as unity) within and on the surface of the body; ζ is the temperature of the surrounding vacuum.

M. Poisson assumes that $u - \zeta$ or v is small, or perhaps rather (as appears to us) that certain multipliers of this quantity are small, so that k and p may be expanded in terms of v, and high powers of this quantity may be omitted. He thence deduces the following equation as expressing the permanent temperature of a bar heated at one extremity; the length of the bar being indefinitely great:

8. $v = \left[1 - \frac{\theta}{3}(\gamma - 2m)\right]\theta e^{-gx} + \frac{\theta^2}{3}(\gamma - 2m)\,e^{-2gx}$; where $\gamma = \log_e 1{\cdot}0077$, and m is undetermined, but depends on the manner in which the conductivity varies with the temperature. (Théorie de la Chaleur, Art. 105.)

On this result we must make some remarks. In the first place, we conceive that by a slip of the pen M. Poisson has given a wrong value to γ; it appears to be properly $\frac{1}{2}\log_e 1{\cdot}0077$. The quantities γ and m result from the expansion of p and k in the form $p + p\gamma u$, $k + kmu$. In the next place, we find some difficulty in understanding *what* the quantity m actually is supposed to be. If M. Poisson conceives, as he leads us to believe in his preface (p. 6), that Dulong and Petit's law is applicable to the interior as well as to the exterior flow of heat, we cannot see how he regards m as undetermined. We should have thought, that if it be admissible to expand in terms of v at all, m must have been known. Perhaps M. Poisson saw a difficulty in admitting this, arising from the circumstance that $\gamma - 2m$ might (and it appears to us it would) turn out to be negative, and thus disprove the whole theory. The phrase which M. Poisson makes use of is this: *Quant à la constante* m, *elle depend de la manière dont la conducibilité varie avec la température; et sa valeur n'est pas non plus connue.* (p. 255.)

IV. The theory suggested by the author of this report adopts all the results of the hypothesis of Fourier. In this case v will not express the *temperature* as measured by an air-thermometer, but a certain function of that temperature. We have already given the function which appears to us to be the proper one. It is deduced by the following reasoning. Let θ represent the temperature, or rather the excess of temperature above that of the surrounding vacuum; then since Fourier's equations hold good, we have $\frac{dv}{dt} = -\alpha v$, where α is a quantity which depends on the radiating power.

But by Dulong and Petit's formula,

$$\frac{d\theta}{dt} = -\beta\,(a^{\theta} - 1)$$

$$\therefore \frac{dv}{d\theta} = \frac{\alpha}{\beta} \cdot \frac{v}{a^{\theta} - 1},$$

$$\text{and } \log v = \frac{\alpha}{\beta \log_e a} \log A\,(1 - a^{-\theta})$$

$$v^{\frac{\beta \log_e a}{\alpha}} = A\,(1 - a^{-\theta}).$$

If $\beta \log_e a = \alpha$, this equation is reduced to

$$v = A\,(1 - a^{-\theta}).$$

To the collection of formulæ which we have extracted from the writings of Fourier, Poisson, and Libri, we may add the following, which apply to experiments of the simplest kind.

9. On Libri's hypothesis, the permanent state of temperature in a small uniform bar of indefinite length heated at one end is represented (approximately) by the equation

$$v = A\,e^{-gx} + \frac{A^2 \log_e a}{6}\,e^{-2gx}.$$

The demonstration of this proposition is as follows:

The equation of motion is

$$\frac{d^2 v}{dx^2} = \lambda\,(a^{v} - 1), \text{ where } a = \sqrt[20]{1{\cdot}165} \text{ according to Dulong and Petit.}$$

$$\text{By expansion, } \frac{d^2 v}{dx^2} = \lambda \left\{ v \log_e a + \frac{v^2}{2} (\log_e a)^2 \right\}$$

$$= g^2 v + \frac{g^2}{2} \log_e a \,.\, v^2 \text{ nearly.}$$

$$\text{Assume } v = A\,e^{-gx} + V,$$

$$\therefore\ A\,g^2 e^{-gx} + \frac{d^2 V}{dx^2} = A\,g^2 e^{-gx} + g^2 V + \frac{g^2}{2} \log_e a \,.\, v^2;$$

$$\text{consequently } \frac{d^2 V}{dx^2} = g^2 V + \frac{g^2}{2} \log_e a \,.\, A^2 e^{-2gx},$$

$$\text{whence } V = \frac{A^2 \log_e a}{6}\,e^{-2gx}$$

$$\text{and } v = A\,e^{-gx} + \frac{A^2 \log_e a}{6}\,e^{-2gx}.$$

10. On Fourier's hypothesis, the temperature at the extremity of a like bar, when its length is not sufficiently great to be regarded as infinite, is $v' = C\,u$, where u is the temperature of the heated extremity, and C is a constant, not depending on u.

The equations of motion are

$$\frac{d^2 v}{dx^2} = \frac{2h}{kl}\,v; \text{ and } \frac{dv}{dx} + \frac{h}{k}\,v = 0^{*}, \text{ at the extremity of the bar.}$$

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* Fourier, arts. 74 and 124; Kelland, arts. 53 and 57.

The solution of the former is

$$v = \mathrm{A}\, e^{-x\sqrt{\frac{2h}{kl}}} + \mathrm{B}\, e^{x\sqrt{\frac{2h}{kl}}},$$

which, when substituted in the latter equation, gives for the extremity of the bar whose length is b,

$$\mathrm{B}\, e^{b\sqrt{\frac{2h}{kl}}} = \mathrm{A}\, e^{-b\sqrt{\frac{2h}{kl}}} \frac{\sqrt{2k} - \sqrt{hl}}{\sqrt{2k} + \sqrt{hl}}$$

$$\text{and} \therefore v = \mathrm{A} \left\{ e^{-x\sqrt{\frac{2h}{kl}}} + \frac{\sqrt{2k} - \sqrt{hl}}{\sqrt{2k} + \sqrt{hl}} e^{-(2b-x)\sqrt{\frac{2h}{kl}}} \right\}$$

$$\text{when } x = 0,\ u = \mathrm{A} \left\{ 1 + \frac{\sqrt{2k} - \sqrt{hl}}{\sqrt{2k} + \sqrt{hl}} e^{-2b\sqrt{\frac{2h}{kl}}} \right\}$$

$$\therefore \mathrm{A} = \mathrm{E}\,(\sqrt{2k} - \sqrt{hl})\, u;$$

abbreviating the reciprocal of $\sqrt{2k} + \sqrt{hl}$

$$+ (\sqrt{2k} - \sqrt{hl}) e^{-2b\sqrt{\frac{2h}{kl}}} \text{ by E.}$$

Hence

$$v = \mathrm{E}u \left\{ (\sqrt{2k} + \sqrt{hl})\, e^{-x\sqrt{\frac{2h}{kl}}} + (\sqrt{2k} - \sqrt{hl})\, e^{-(2b-x)\sqrt{\frac{2h}{kl}}} \right\}.$$

When $x = b$, $v' = \mathrm{C}\, u$.

11. *Cor.* The temperature *at any point* of a bar of finite length is represented by

$$v = \mathrm{E}u \left\{ (\sqrt{2k} + \sqrt{hl})\, e^{-x\sqrt{\frac{2h}{kl}}} - (\sqrt{hl} - \sqrt{2k})\, e^{-(2b-x)\sqrt{\frac{2h}{kl}}} \right\}.$$

The expression shows that the temperature is the difference of two quantities; the one due to the heating at the one extremity, and the other following a corresponding law, and due to the cooling at the other extremity of the bar.

12. On Libri's hypothesis, the expression for the temperature at the extremity of a bar heated permanently at the other extremity is

$$v' = 2p_o\{\sqrt{p^2 q^2 + qu} - pq\} + \frac{(\sqrt{p^2 q^2 + qu} - pq)^2}{q_o},$$

where u is the temperature at the heated extremity of the bar, and p, q, p_o, q_o, are constants. This proposition is of some importance, but from the want of experiments we do not think it necessary to exhibit the values of the constants in full.

The demonstration is as follows: since

$$\frac{d^2 v}{dx^2} = g^2 \left(v + \frac{v^2}{2} \log_e a\right), \text{ and } \frac{dv}{dx} + f\left(v + \frac{v^2}{2} \log_e a\right) = 0$$

at the extremity of the bar, we obtain

$$1. \quad v = \mathrm{A}\, e^{g(b-x)} + \mathrm{B}\, e^{-g(b-x)} + \frac{\mathrm{A}^2 \log_e a}{6} e^{2g(b-x)}$$

$$+ \frac{\mathrm{B}^2 \log_e a}{6} e^{-2g(b-x)} - \mathrm{A}\,\mathrm{B} \log_e a.$$

2. From the second equation

$$B=\frac{g-f}{g+f}A-\frac{4f^3A^2\log_e a}{3(g+f)^3}.$$

Also u the temperature at the heated extremity is of the form $2p\,A+\frac{A^2}{q}$:

$$\therefore A=-pq+\sqrt{p^2q^2+qu}$$

and $v'=2p_o\,A+\frac{A^2}{q_o}$, in which p_o and q_o differ from p and q in not containing e^{gb}, e^{-gb}; or may be deduced from them by writing $b=0$;

$$\therefore v'=2p_o\{\sqrt{p^2q^2+qu}-pq\}+\frac{(\sqrt{p^2q^2+qu}-pq)^2}{q_o}.$$

13. The expression for the permanent temperature at one extremity of a bar heated at the other extremity, determined on M. Poisson's hypothesis, differs from the foregoing only in having $\frac{\gamma-2m}{3}A^2$ instead of $\frac{\log_e a}{6}A^2$ as the coefficient of $e^{2g(b-x)}$, $\frac{\gamma-2m}{3}B^2$ instead of $\frac{\log_e a}{6}B^2$ as that of $e^{-g(b-x)}$ and 2γ instead of $\log_e a$ as the coefficient of the constant term in v.

14. The expression for the same permanent temperature derived from the fourth hypothesis is $1-a^{-v'}=C(1-a^{-u})$.

15. When a bar, so large as that it may be considered infinite, is heated at one end to the constant temperature a, and kept at the other to the constant temperature b, as assumed in formula 1, the state of temperature at any point, as deduced from M. Poisson's theory, is given by the equation

$$v-a+\frac{m}{2}(v^2-a^2)+(a-b+\frac{m}{2}\overline{a^2-b^2})\;\frac{z}{e}=0.$$

The proof of this proposition is as follows:

Since the bar is very large, the effect of radiation is zero (at least near the centre of the bar). Therefore the equation of motion is $\frac{d}{dz}\cdot\left(\frac{dv}{dz}\right)=0$,

or $k'\frac{dv}{dz}=c$.

Now Poisson's approximates by supposing $k'=k+kmu$.

Hence the equation is immediately integrable, and the result is as above given.

16. The corresponding equation due to the fourth hypothesis is

$$1-a^{-v}=1-a^{-a}+\frac{a^{-a}-a^{-b}}{e}z;$$

the a which is affected with an index being Dulong and Petit's a.

We have not thought it relevant to our present subject to point out the difference which exists between hypotheses III. and IV.; as, however, we have given only approximate formulæ corresponding with the former hypothesis, it may be proper to mention, that, for expressions not involving the time, the essential difference between the formulæ will be seen by the difference of sign of the quantity which corresponds with m. It will be seen that on hypothesis III. the form of the result in this case is $v + \frac{m}{2} v^2 = a - \beta z$, whilst the approximate form on hypothesis IV. is

$$v - \frac{m}{2} v^2 = a - \beta z.$$

We may add, that if we assume $k = a\, a^v$, the correct equation for hypothesis III. will be $a\, a^v \frac{d v}{d x} = c$, which gives

$$\frac{a}{\log_e a}\, a^v = c\, x + c'.$$

When the time enters into the expression, no analogy exists between the formulæ deduced on the two hypotheses.

If we were in possession of a number of experiments adapted for the purpose, it would be desirable that the constants in formula (12) and (13) were more fully expressed. When such experiments shall have been made, a very little trouble will suffice to effect this. Should it appear, moreover, that experiments bearing on formulæ different from that which we have given can be more easily performed, the corresponding expressions may be readily deduced from the equations given above.

II. We proceed now to the second division of our report. We have to inquire to what extent theory has been tested by experiment. In prosecuting this inquiry we shall be led to examine for ourselves such of the formulæ as appear to be parallel to the experiments we possess. We hope by so doing to point out the facility with which experiment is made available, as well as practically to exhibit the neglect or want of attention which this department of science has suffered.

We turn first to the experiments described in M. Biot's 'Traité de Physique' (1816), tom. iv. Those which follow were made with the design of testing the formula for the permanent state of heat at any point of a very long bar heated at one end. The author himself compares them with the formula, which, as we have said before, was discovered by him, but never completely demonstrated.

(1.) The first experiment was made with a bar of iron, plunged at one extremity into a bowl of mercury at 102¼° cent.: along the bar were ranged eight thermometers at various distances from each other. The observations were made after the state of the temperature, as indicated by the thermometers, had arrived at permanency; and the length of the bar was so great that the temperature of its free extremity did not sensibly differ from that of the air. The following table contains the results of this experiment reduced to the centigrade scale. The distances are expressed in decimetres, and the numbers in the third column express the permanent state of the excess of temperature of the corresponding points of the bar above that of the surrounding air. This latter temperature was 16¼°.

No. of therm.	Dist. from Mercury.	Excess of temp. above that of the air.
0	0	86·25
1	2·115	29·375
2	3·115	17·5
3	4·009	11·25
4	4·970	7·1875
5	5·902	4·6875
6	7·777	2·1875
7	9·671	1·25
8	11·556	insensible

The distance of the end of the bar from the mercury was 27·342 decimetres.

I. The following table exhibits the temperatures which should exist, as calculated by the Cor. to formula 2; *i.e.* on the first, or Fourier's hypothesis. It is copied from Biot, vol. iv. p. 672, and reduced to the cent. scale. The constants are determined by thermometers 1 and 3.

Therm....	0	1	2	3	4	5	6	7
Result....	85·6	29·375	17·7	11·25	6·9375	4·3125	1·6625	·6375

II. Let us calculate the temperatures on Libri's hypothesis, by means of formula 9.

We have $\log_e a = \cdot 00763606$, and if we denote one-sixth of this by c, our equation becomes

$$v = \mathrm{A}\,e^{-gx} + c\,(\mathrm{A}\,e^{-gx})^2, \text{ which, being solved,}$$

gives $\mathrm{A}\,e^{-gx} = \dfrac{\sqrt{4cv+1}-1}{2c}$;

and therefore $e^{-g(x_3-x_1)} = \dfrac{\sqrt{4cv_3+1}-1}{\sqrt{4cv_1+1}-1}$.

These two equations determine g and A by means of the first and third thermometers; viz.

$$e^{-g} = \cdot 6093, \text{ and } \mathrm{A} = 80\cdot 855.$$

The results of the calculation are the following:

0	1	2	3	4	5	6	7
89·2	29·375	17·6	11·25	6·95	4·358	1·72	·67

III. On M. Poisson's hypothesis we have formula 8, viz.

$$v = \left\{1 - \frac{\theta}{3}(\gamma - 2m)\right\}\theta e^{-gx} + \frac{\theta^2}{3}(\gamma - 2m)e^{-2gx}:$$

where θ is the temperature at the heated extremity of the bar, and γ, as corrected above, is ·003818. To compare this formula with experiment, we have supposed that g has the same value as we found it to have according to the preceding hypothesis. This supposition cannot, to any considerable extent, affect the results; and we could not obtain g by any other direct means. We get from thermometers 0 and 1, $\gamma - 2m = \cdot 00153$, and thence obtain the following table of results:

0	1	2	3	4	5	6	7
86·25	29·375	17·78	11·36	7·05	4·43	1·75	·69

IV. Lastly, on the hypothesis that the flow of v is proportional to v, both within and at the surface of the medium. We reduce v to thermometric temperature by means of the equation $v = \mathrm{A}\,(1 - a^{-\theta})$ which is not strictly accurate except for the air thermometer; and we determine the constants from thermometers 3 and 5. The following are the results:

0	1	2	3	4	5	6	7
90·3	27·7	17·2	11·25	7·19	4·6875	2	·86

It may be proper to remark, that although we have adopted MM. Dulong and Petit's value of a, we are aware that for radiation in *air*, so far as the formula approximates to the circumstances, this value of a is too small.

(2.) The next experiment given by M. Biot (p. 673) is the following:

A bar of iron was held for many hours plunged in melting lead. The vessel containing the lead was heated from below by means of a lamp and current of air. To prevent the temperature from increasing, a small bar of unmelted lead was kept constantly in the vessel. The temperature of the air was kept uniformly at 18°·125. The unit of length was taken as the distance between the first and second thermometers. The following table contains the results:

No. of therm.	Dist. from extremity.	Temperature above air.
1	2·23077	76·875
2	3·23077	47·1875
3	4·12019	29·375
4	5·08172	17·8125
5	6·02883	10·625
6	7·89903	3·75
7	9·78363	1·5625

I. The result of calculation on the first hypothesis, the errors being arranged so that there shall be the smallest possible total error amongst the first four thermometers, is given by M. Biot as follows:

1	2	3	4	5	6	7
77·575	46·7625	29·275	17·975	11·125	4·3125	1·6625

II. On the second hypothesis the values of the constants are

$$A = 206\cdot9 \text{ and } \log e^{-g} = -\,\cdot20955,$$

as determined from the first and third thermometers. The table is as follows:

1	2	3	4	5	6	7
76·875	46·07	29·375	18·22	11·44	4·6	1·85

III. By the third hypothesis, retaining the value of g given by the second, we get $\gamma - 2m = \cdot003206$, a result probably too great; and there arises the following table:

1	2	3	4	5	6	7
76·875	47·76	29·375	18·23	11·45	4·6	1·85

IV. The computations on the fourth hypothesis give

1	2	3	4	5	6	7
76·875	45·2	29·375	18·74	12·34	5·73	2·45

By selecting other observations to determine the constants, we might, had it been requisite, have made the results more conformable in this case.

(3.) M. Biot's third experiment was made on a bar of copper, plunged at one extremity into melting lead. It carried fourteen thermometers, of which, however, eleven only were available. The unit of distance was 101 millimetres, and the temperature of the surrounding air 15·75°. The following table exhibits the result:

No. of therm.	Dist. from extremity.	Temperature above air.
4	5·25	80·5
5	6·25	65·75
6	7·25	53·75
7	8·25	43·75
8	9·25	35·5
9	11·25	24·
10	13·25	15·7
11	15·25	11·
12	17·25	7·5
13	19·25	5·25
14	21·25	3·75

I. The results of M. Biot's computation, so as to give the smallest possible amount of error amongst the thermometers 4, 5, 6 and 7, are

4	5	6	7	8	9	10	11	12	13	14
80·6	65·78	53·82	43·8	35·75	23·81	15·85	10·56	7·03	4·68	3·12

II. On the second hypothesis A = 199·57 and log e^{-g} = − ·08278, and the following are the results:

4	5	6	7	8	9	10	11	12	13	14
80·5	65·34	53·32	43·6	35·72	24·07	16·3	11·06	7·52	5·12	3·49

III. M. Poisson's method, when the value of e^{-g} deduced from the preceding hypothesis is retained, gives $\gamma - 2m = \cdot0031825$; and we have

4	5	6	7	8	9	10	11	12	13	14
80·5	65·55	53·5	43·75	35·84	24·15	16·35	11·09	7·54	5·15	3·5

IV. The fourth hypothesis gives

4	5	6	7	8	9	10	11	12	13	14
84·9	67	53·75	43·51	35·5	24	16·45	11·39	7·9	5·5	3·8

The next series of experiments similar to the above we obtain from the work of M. Despretz, entitled 'Traité de Physique.' The author read before the Academy of Sciences in 1821 a memoir, the object of which is to measure in a number of substances the conductive power relative to heat. It is published in the 'Mémoires des Sçavans Etrangers.' An account of it appears in the 'Annales de Chimie,' t. xix. (1821) p. 97, by M. Fourier, and it is extracted in works referred to above (1825). We have added the examination of the four formulæ by means of these experiments. We shall find that they all come very wide of the results, even in cases differing in no apparent particular from those given by M. Biot. This is remarkable, for all the formulæ agree well with M. Biot's experiments. To what circumstance can we attribute this fact? It cannot be supposed that the presence of the air should vitiate one series of experiments without affecting the other, in which everything else is similar. We can only suggest, that the bars whose conducting powers were examined, were not sufficiently long to be regarded as infinite. Unfortunately M. Despretz does not mention their length. The experiments were as follows:

(4.) The stationary excesses of temperature above that of the air, at different points of a bar of copper taken at equal distances from each other, were found to be as follows:

No. of ther....	1	2	3	4	5	6
Exc. of temp.	66·36	46·28	32·62	24·32	18·63	16·18

The temperature of the air was 17·08°, and the distance between two consecutive thermometers ten centimetres.

The following are the calculated results, by the four hypotheses respectively, using in each case the results of the first and third thermometers for the determination of the constants.

I.

1	2	3	4	5	6
66·36	46·45	32·62	22·83	15·98	11·19

II. Here e^{-g} ·714 and A = 61·54.

1	2	3	4	5	6
66·36	46·45	32·62	22·83	15·98	11·19

III. e^{-g} is assumed to be equal to ·714, and $\gamma - 2m$ is determined to be .003271.

1	2	3	4	5	6
66·36	46·28	32·62	23	16·3	11·47

IV.

1	2	3	4	5	6
66·36	46	32·62	23·5	17·1	12·5

(5.) A bar of iron circumstanced as the preceding. The temperature of the air was 17·34°.

No. of therm....	1	2	3	4	5	6
Exc. of temp....	62·9	36·69	20·52	12·32	8·19	6·61

Calculations.

I.

1	2	3	4	5	6
62·9	35·92	20·52	11·72	6·7	3·83

II. Gives $e^{-g} = \cdot 589$, A = 58·7, and

1	2	3	4	5	6
62·9	36·37	20·52	12·17	7·5	4·2

III. Assumes $e^{-g} = \cdot 589$, and gives $\frac{\theta^2}{3}(\gamma - 2m) = 5\cdot 2705$.

1	2	3	4	5	6
62·9	35·77	20·52	11·98	7	4·1

IV.

1	2	3	4	5	6
62·9	38	20·52	12·28	7·4	4·7

(6.) A bar of pewter. The temperature of the air = 17·34°.

No. of therm....	1	2	3	4
Exc. of temp....	63·41	35·17	21·52	15·52

Calculations.

I.

1	2	3	4
63·41	36·93	21·52	12·5

II. Gives $\log e^{-g} = -\cdot 22408$ and A = 58·83.

1	2	3	4
63·41	36·69	21·52	12·73

III. Assumes $\log e^{-g} = -\cdot 22408$, and gives $\frac{\theta^2}{3}(\gamma - 2m) = 4\cdot 683$.

1	2	3	4
63·41	36·72	21·52	12·7

IV.

1	2	3	4
63·41	36·14	21·52	13·18

(7.) A bar of zinc. The temperature of the air = 5·62°.

No. of therm....	1	2	3	4
Exc. of temp....	64·17	38·02	25·43	17·93

Calculations.

I.

1	2	3	4
64·17	40·4	25·43	16·01

II. Gives $\log e^{-g} = -\cdot 19184$, A = 59·64.

1	2	3	4
64·17	40·21	25·43	16·17

III. Assumes $\log e^{-g} = -\cdot 19184$, and gives $\frac{\theta^2}{3}(\gamma - 2m) = 4\cdot 656$.

1	2	3	4
64·17	40·2	25·43	16·18

IV.

1	2	3	4
64·17	39·69	25·43	16·6

(8.) A bar of lead. The temperature of the air = 17·12°.

No. of therm. ...	1	2	3	4
Exc. of temp. ...	65·13	29·42	14·93	9·99

Calculations.

I.

1	2	3	4
65·13	31·18	14·93	7·18

II. Gives $\log e^{-g} = -\cdot 30776$, A = 60·45.

1	2	3	4
65·13	30·89	14·93	7·38

III. Assumes $\log e^{-g} = -{\cdot}30776$, and gives $\frac{\theta}{3}(\gamma - 2m) = 4{\cdot}511$.

	1	2	3	4
	65·13	30·9	14·93	7·27
IV.	1	2	3	4
	65·13	30·12	14·93	7·5

(9.) A bar of white marble. The temperature of the air = 17·15°.

No. of therm. ...	1	2	3	4
Exc. of temp. ...	63·91	6·08	1·95	1·47

Calculations.

I.	1	2	3	4
	63·91	11·16	1·95	·3406

II. Gives $\log e^{-g} = -{\cdot}74249$, A = 59·40.

1	2	3	4
63·91	10·9	1·95	·352

III. Assumes $\log e^{-g} = -{\cdot}74249$, and gives $\frac{\theta^2}{3}(\gamma - 2m) = {\cdot}644$.

	1	2	3	4
	63·91	11·35	1·95	·379
IV.	1	2	3	4
	63·91	10·18	1·95	·37

Of the other formulæ which have been tested by experiment we do not make much account, since it is our impression that the experiments were conducted rather with a view to *illustrate* the formulæ than to try the validity of the principles on which they depend. We instance the following: it is taken from Fourier's Memoir, which contains several others, 'Mém. de l'Institut,' tom. v. p. 217. See also Kelland, 'Theory of Heat,' p. 60.

Three thermometers were placed at different points of a solid ring, at intervals of one-eighth of the circumference: a fourth was so placed that the third lay midway between it and the first. The temperatures observed were 66°, $50\frac{7}{12}$°, 44°, and 34·353° + $17\frac{2}{3}$°, respectively.

The equation which results from formula (3) is $\frac{v_1 + v_4}{v_3} = \left(\frac{v_1 + v_3}{v_2}\right)^2 - 2$, where v_1, v_2... are the excesses of temperature of the different thermometers above that of the air.

By computation, it appears that the first side of this equation is 3·140, and the second 3·143, a difference hardly appreciable.

The second and third hypotheses give formulæ which are merely corrections on the first. In this case, therefore, no correction is required.

In computing the result on the fourth hypothesis, our equation is

$$\frac{1 - a^{-\theta_1} + 1 - a^{-\theta_4}}{1 - a^{-\theta_3}} = \left(\frac{1 - a^{-\theta_1} + 1 - a^{-\theta_3}}{1 - a^{-\theta_2}}\right)^2 - 2,$$

and the first side is equal to 2·96, the second to 2·875; a coincidence which, though not so close as the former, is very far within the error due to the effect of the air. We are almost inclined to believe that the very closeness of the coincidence by the former process proves the incorrectness of the formula to represent what it is intended to express.

We are now, in the last place, to exhibit the results of an experiment of a different kind, and one which, had it been well made, we should have deemed most important. It is taken from M. Biot's work, 'Traité de Physique,' iv. 676.

(10.) A rod composed of a mixture of tin and bismuth in equal portions, which melts at the temperature of boiling water, was plunged at one extremity into a basin of mercury. The mercury was kept successively for a long time at different constant temperatures, by means of a lamp placed below it. A thermometer was adjusted to the other extremity of the rod, in a little capsule filled with mercury. Observations of the temperature indicated by this thermometer, corresponding with each stated temperature of the mercury in the basin, were made, when the state had become stationary. The following table exhibits the corresponding excesses of temperature of the mercury and of the thermometer above that of the air. The latter was 20°.

Excess of temp. at heated end	10·25	19·75	29·25	49	69·75	80
Corresp. excess at other extr^{y}.	3	5·5	8	10·5	11·75	12·5

Before we compare this table with theory, it is right that we express our belief that there has been some mistake in the observations. We think this will be made out when it is seen that the following is the order of elevations of the upper thermometer, due to elevations of temperature of the heated end.

For the first 10°·25 the thermometer rose 3°;
For the second 9°·5 the thermometer rose 2°·5;
For the third 9°·5 the thermometer rose 2°·5;

in which the rise of the thermometer is nearly, but not quite, proportionate to that of the mercury; but

For the fourth 19°·5 the thermometer rose only 2°·5.

This we think very unlikely. We should expect to find the proportion of the increase of temperature of the thermometer to that of the mercury *continually* diminish as the absolute temperature increases. The following are, however, the ratios as given by the above table:

$$\frac{1}{3{\cdot}146},\quad \frac{1}{3{\cdot}8},\quad \frac{1}{3{\cdot}8},\quad \frac{1}{7{\cdot}9},\quad \frac{1}{16{\cdot}6},\quad \frac{1}{13{\cdot}66}.$$

If this be correct, the law is discontinuous.

Calculations.

M. Biot gives the following results as calculated by an empirical formula:

1	2	3	4	5
3·7	6·18	8	10·37	11·75

I. From formula 10, $v = C u$.

1	2	3	4	5	6
3	5·78	8·56	14·34	20·41	23·41

II. and III. On Libri's or Poisson's hypothesis we have approximately (from 12 and 13) $v = C u - D u^2$.

If we apply experiments (3.) and (5.) to obtain the constants C and D, there results

1	2	3	4	5	6
4·06	5·86	8	10·03	11·75	12

IV.

1	2	3	4	5	6
2·9	4·61	6·66	10·5	14	15·68

It must be observed here, that we have only one constant to be determined by experiment. We must not expect, therefore, to find so close an agreement as when we have two.

We are not ignorant that there are a vast number of experiments on radiation and conduction to which we have not referred. Our reason for omitting the mention of some of the most valuable is, that we desire to confine our attention strictly to the matter in hand—the examination of theoretical formulæ by experiments calculated to test their accuracy.

III. We hasten, then, to the third part of our Report. We propose very briefly to reflect on the consequences deducible from the computations we have entered into; and to conclude by adding a few remarks tending to suggest the proper mode of conducting experiments which shall serve a better purpose in effecting the object of establishing theory. We may observe then, 1st, that experiments on the permanent state of temperature at different points of a long bar of a good conducting substance, and which radiates into air, are utterly valueless in this matter. To prove this, we will write down the difference between the calculated and observed values of the temperature for a few cases.

Exp. I.

Therm.	0	1	2	3	4	5	6	7
Formula I.	·65	0	·2	0	·25	·375	·525	·6125
II.	2·95	0	·1	0	·9275	·3275	·4675	·58
III.	0	0	·28	·11	·1375	·2575	·3375	·56
IV.	4·05	1·675	·3	0	·0025	0	·1875	·34

It is altogether impossible to decide which is the best formula from these results. Apparently Formula I. is as good as any of them, and yet we are sure, *à priori*, that it is absolutely erroneous. The ratios of the error to the whole temperature when greatest are, for the different formulæ,

I. ·49, II. ·465, III. ·458, IV. ·272.

These ratios are very considerable, and as they all arise at the point of greatest distance from the heated extremity, they prove clearly enough that the effect due to the presence of the air is far greater than that which arises from the difference of radiation between Newton's law and the law of nature. But even if experiments of this kind were made in a vacuum, it is probable that the law of change would be found to remain so uniform as to admit of its being represented by either of the equations resulting from the second, third, or fourth hypothesis. Nor will our conclusions be more satisfactory on referring to M. Despretz's experiments. Let us write down the errors in

Exp. V.

Therm.	1	2	3	4	5	6
Formula I.	0	·77	0	·6	1·49	2·78
II.	0	·32	0	·15	·69	2·41
III.	0	·92	0	·34	1·19	2·51
IV.	0	1·32	0	·04	·79	1·91

The maximum ratios of the error to the whole temperature are

I. ·42, II. ·36, III. ·37, IV. ·28.

We must remark again, that this experiment, as contrasted with the foregoing, presents us with most anomalous results. Both were made on a bar of iron; the temperature of the surrounding air was nearly the same in both; the extreme temperatures of the former lie beyond those of the latter on each side; and yet the former verifies, or nearly so, all the formulæ,—the latter disproves them all. We trust neither; nor do we think the difference can be attributed to the coating with which the iron was furnished in the second experiment, although that might produce some effect. We feel, therefore, utterly unable to draw any conclusion from these experiments. We shall experience the same difficulty if we proceed to examine the other results in the same way. If we confined our attention to experiments (1.), (2.) and (3.), we might conclude that *all* the formulæ are correct; if to (8.) and (9.), we should certainly conclude that *all* are incorrect. Nor is it easy to say which is the best from the former test, or which is the worst from the latter. Seeing, then, that agreement with experiment is no test of truth, it is not too much to argue that disagreement is no test of error. We must eliminate the effect of the air, or be provided with experiments *in vacuo*, before we can form our conclusions, unless we can be furnished with experiments of a much more searching character than these.

2. It is hardly necessary to call attention to the insufficiency of the class of experiments which was made by M. Fourier, and of which we have exhibited one specimen. The results for the ring, it is true, are not so obvious that they might be deduced from popular reasoning, and we must give M. Fourier great credit for selecting these results in order to show the agreement of his theory with experiment; but as we are now in want of a means of *disproving* rather than of establishing theories, we must look for results of a totally different character. We shall point out where such are to be found by and by.

3. We think we may consider that experiment (10.) shows the inaccuracy of the first formula; it fails, however, to give any preference to one of the other three. The table of errors is as follows:

No.	1	2	3	4	5	6
I.	0	·28	·56	4·84	8·66	10·91
II. & III.	1·06	·36	0	·53	0	·5
IV.	·1	·89	1·34	0	2·25	3·18

The maximum ratio of error to the whole temperature is

I. ·87, II. & III. ·35, IV. ·25.

It is needless to comment on these results. None of them are sufficiently close to warrant any favourable conclusion, and the first is so wide, that, were there no other reasons, we should on this account be disposed to reject the corresponding formula, and with it the axioms on which it depends.

We do not know that any other remarks are called for by a review of the results of theory as contrasted with experiment. What, then, does the whole amount to? We find that there are three distinct ways of theorizing, each adopted, apparently, in accordance with the known laws of nature, but which differ essentially from each other. We do not perceive that our existing experiments bear with greater weight in establishing or in disproving any one of them than it does in establishing or disproving the other two. Each is confirmed by one experiment, each at variance with another. Are we to account for this circumstance from the difficulty of conducting the requisite experiments, or are we not rather to attribute the anomaly to the little regard which has of late years been paid to a certain class of subjects, and especially to the one before us? We are not aware that it has suggested itself to any one experimental philosopher to examine into the laws of conduction. Much labour, it is true, has been bestowed in examining the conductive powers of different substances, and to the results of experiments carried on with this object we naturally look with the hope of extracting a law; but, unfortunately, the nature of the experiments we are presented with is not such as will lead to what we seek. They were not originally conducted with reference to the state of things assumed to exist in theory, and are, in consequence, of less value when allowance is made for the difference between what they express and what theory requires. Now we do not deny that difficulties do attend the experimental examination of this subject, when it is intended to make everything correspond with the state supposed in theory. The chief and greatest of these we conceive to arise from the presence of the air. MM. Dulong and Petit have shown that the quantity of heat carried off by the air is not only very large, but is governed by a law very different from that of ordinary radiation. Means have therefore to be devised for removing this cause of error; but we are far from thinking that the difficulty of effecting this amounts to an impossibility. If MM. Dulong and Petit could succeed in determining the rates of cooling of a body *in vacuo*, we cannot see why others should not succeed in observing the stationary temperature at one point, at least, of a body which radiates *in vacuo*. This leads us to the suggestions with which we shall conclude the present Report. We shall offer two: 1st, as to the most important experiments; 2ndly, as to the mode by which they may be conducted.

It is perhaps chargeable against the theoretical writers on this branch of physics, and especially against M. Poisson, that they have not presented their results in a form sufficiently tangible to direct or suggest the application of experiment to them. It is much to be regretted that no attempt has been made to obviate this. With the view of remedying the state of things to a certain extent, we have exhibited in their most simple forms some of the more obvious conclusions to which the different theories lead. No doubt much might be done in this way, but, until called for by the entry of experimenters on the field, a large and varied collection of formulæ would serve no useful purpose. One class of experiments alone appears amply to suffice for our present purpose. The object being, *to discover a law of conduction*, it will be best attained by the selection of circumstances in which radiation either plays no part at all, or in which its effect is very simple and readily eliminated. The former condition exists in the problem which is solved by formulæ 1, 15 and 16. By selecting a substance of small conducting power, such as marble, and coating the block with a substance which will radiate very slowly, this experiment may be made on a block of no very great dimensions. For many reasons this experiment is well worth trying. It will probably distinguish at once between the three theories. It will certainly offer strong reasons for rejecting either the third or the fourth. Of course it will hardly serve to establish directly either of them. To effect this, we would point out another most important experiment,—*The determination of the state of temperature at one extremity of a bar which is heated at the other extremity*. This experiment should be made on a variety of bars, of different conducting powers and of different lengths. With a set of careful experiments of this nature, we believe we could pronounce, without fear, the true law of conduction. Nor do we think the difficulties attendant on the conduct of the experiments to be at all insuperable. The greatest obstacle is, no doubt, the expense of apparatus; but where we find expense overruled in the prosecution of experimental researches into less important and certainly not more interesting branches of physics, where theory has hardly opened a field for speculation, and where curiosity alone prompts the inquiry, it must excite our surprise that so little has been done in this case, which presents analytical developments of great beauty, and, independently of its close connexion with the favourite theories of light and the discoveries of chemistry, deserves to rank high amongst the physico-mathematical sciences. But, leaving expense out of the question, the real practical obstacle is the presence of the air. We have seen that the *law* of cooling into air is different from that of radiation. Even supposing, therefore, we were in possession of the correct statement of that law, such would be the difficulty of obtaining formulæ from it, that to attempt to eliminate its effect, together with that of radiation, is almost hopeless. If it can be done at all, it must be by means of experiments carried on in air of different elasticities. It has been proved by MM. Dulong and Petit, that "the velocity of cooling of a body due to the sole contact in a gas, depends, for the same excess of temperature, on the density and temperature of the gas; but this dependence is such that the velocity of cooling remains the same if the density and the temperature of the gas change in such a way that the elasticity remains constant." The effect, then, of the presence of the air is to introduce a term which involves a power of the elasticity as one factor, and a function of the excess of temperature as another. The latter function may be determined (perhaps) by means of a number of experiments made at different elasticities. But we should greatly prefer a set of experiments on radiation *in vacuo*. It appears to us, that the difficulty in this case is very much the same as that against which MM. Dulong and Petit had to contend in investigating the kindred law of radiation; and we should conceive that a similar contrivance to that which they used might be adopted to overcome it. All that we require is, that a certain portion of a bar heated at one extremity, radiate *in vacuo*, and that the temperature at two of its points, the other extremity being one, be capable of constant observation. MM. Dulong and Petit made use of a copper balloon which could be exhausted of air, and by means of ice be kept constantly to the freezing temperature, notwithstanding the radiation of the heat from the body within it. A somewhat similar contrivance we conceive would serve for the conduct of the experiment before us. The bar of metal to be experimented on might pass through the balloon and be heated in air, whilst the assumed point of heating might be marked by a thermometer inserted into a hole in the bar just within the balloon. We wish M. Biot had marked his lowest point, not at the surface of the heated mercury, but at a point a little above it; it would have insured greater steadiness in the results. Should any one think of undertaking this experiment, we would recommend that he extend his observations over a wider range of temperatures than M. Biot has done. The thermometer which represents the heated end of the bar should stand permanently at every 5°, from 0° to as high as can be accomplished. It must be borne in mind, that two at least of the observations are requisite for the determination of the constants, except in the case of formula 14. The observations should likewise embrace a succession of bars of different substances, iron, brass, lead, etc., *all* of the same dimensions. Different series of observations should be made, in which the dimensions of the bars have different constant magnitudes, and others in which they have different lengths. All the substances might be coated with the same varnish, so as to render their radiating powers the same. With such experiments, we have no doubt that the law of conduction, although not like the law of radiation, an inference from direct observation, might be readily established, and the science of heat placed on the same footing with the other mathematical sciences. We hope that the Association, in making known the wants of this branch of philosophy, will induce some of the numerous distinguished experimental philosophers whose names appear on their list, to take an interest in this matter.

P. KELLAND.

Report on Poisons. *By* G. L. Roupell, *M.D., F.R.S.*

The complexity of the functions of the animal body, and their liability to disturbance from a number of causes, must be apparent to the most superficial observer. To those who endeavour to explain what takes place during the disturbed performance of the vital actions, many difficulties present themselves; opposite causes occasion one common and similar result, and the same agent will produce very different effects under circumstances apparently analogous. Whilst, however, there may be thus many conflicting processes exhibited to us, we are satisfied that there are leading principles and general laws in operation which it is our great aim to seek for and discover. We cannot avoid allowing the proposition, "That under actually corresponding circumstances similar effects must ensue." Should then differences exist in the effects of any substance upon the system, as a poison for example, we naturally refer them to modifying influences; at the same time that we explain the production of similar effects from opposite causes, by the agency of fundamental principles, proving simplicity in the laws which regulate our frames.

The object of my former communications has been to illustrate the effects of those poisons which induce an alteration in the vascularity of the different tissues with which they may come in contact, and to portray the appearances exhibited by dissection: on the present occasion some views will be stated concerning the operation of an agent which is constantly eliminated from the system, the effects of which, although not indicated by obvious local changes or capable of elucidation by drawings, appear nevertheless to be highly deserving of consideration and study. Carbonic acid is the agent alluded to; one highly interesting, first, from its producing very marked and injurious consequences if applied in any way to the human body, either internally or externally; secondly, from its immediate connection with one highly important function of our system; thirdly, from the analogy of its effects with some most serious maladies; and fourthly, from the causes which influence its secretion.

It cannot here be requisite to insist upon the necessity for the rejection of all effete matter from the body, or to show the importance of the changes perpetually going on in the circulating fluids. These points will readily be conceded to me; nor will the mischief be questioned arising from the presence of certain principles in the blood, such as bile or urea; but, while these substances have deservedly occupied much attention of late, we are neglectful of an agent far more injurious. The ducts of the liver may be partially, if not entirely closed, for months; the kidneys may be removed, or the secretion of urine may be suspended for more than a week, yet life during that time may be preserved; but should the elimination of carbonic acid from the lungs be prevented for a few minutes, nay, only for a few seconds, life will be placed in imminent peril, if not irrevocably destroyed.

We are well aware that carbonic acid is generated by various processes, for example, by decomposition, both of animal and vegetable bodies, by combustion, by fermentation, as well as by the respiratory apparatus. We are also aware that plants yield it by night; that it is exhaled from the earth in certain situations, and that it is disengaged by chemical action, from compounds of which it forms an ingredient. We are certainly ready to admit that air charged with this gas, from whatever source it may be produced, is positively and highly detrimental. Sir Humphry Davy deemed it not beneath his notice to investigate the condition of the atmosphere rendered impure by persons crowding together in large or public assemblies, and showed that carbonic acid was present in excess in the vitiated air of such meetings. The experiments of MM. Allen and Pepys, Lavoisier and Seguin, Davy and Bèrzelius, concerning the exact quantity of this gas evolved during respiration, still occupy the attention of the scientific world; but its effects upon the system seem to me to be yet greatly overlooked and disregarded. The injurious consequences which it produces to those who, by accident or design, may be exposed to its effects, have led to less useful results, practically, than might have been anticipated from the nature of the symptoms, and the interesting phenomena which result from its action. Year after year numbers flock to witness the experiment of submitting a wretched animal to the deadly atmosphere of the "Grotto del Cane," without drawing those deductions, or deriving that advantage from its sufferings, which alone can palliate or justify their infliction.

Carbonic acid has many sources out of the body, and it is abundantly furnished by respiration. The lungs, however, are by no means its only outlet from the animal body. It is given off by the skin, it is secreted as well by the serous as mucous membranes*, points of much interest, not only as affording an example of vicarious action, but as explanatory of various bodily disorders. It cannot here be necessary to controvert old errors respecting the source of the carbonic acid yielded by respiration, nor to dwell upon the more probable views of modern times. The opinions and experiments of Mr. Edwards, which prove that this acid is extricated from the lungs, although no oxygen is respired†, the observations of Professor Magnus, and his conclusions that all blood contains carbonic acid, the belief of Müller that the quantity held in solution in it‡ is sufficiently large to account for the whole exhaled by the lungs, are facts well known to all whom it is my pleasure to address. Thus we find that a most important series of changes takes place during the circulation of the blood leading to the formation of carbonic acid, which is set free from various surfaces, chiefly, however, from the parietes of the air-cells, which allow it to pass through them in order to be exhaled§. Next we find that many circumstances greatly influence the amount of this gas yielded by respiration; these may be ranked in two classes, one of which may be considered as natural or regular, the other as accidental or abnormal. With regard to the first of these, to the regular performance of the functions of the system, we find that more carbonic acid is eliminated during the day than by night; that it increases at day-break, and diminishes at sunset‖; that it is produced in larger quantity by exercise and during digestion; and, what is extremely interesting, we see a tendency to equilibrium in the whole amount; for if given off in excess at one time, at another it will, as a consequence, be lessened. With regard to the second class of circumstances which influence the secretion, we find that it is diminished by depressing passions, debilitating causes, low diet, and injuries to the par vagum¶.

If we now look to the actual effects of carbonic acid, when placed in contact with the living body, many interesting consequences result which serve to indicate its use in the human economy, and its agency in disease.

It imparts an acid taste, produces a sense of burning in the uvula**, and acts instantaneously as a powerful irritant to the muscles of the larynx, occasioning by their spasmodic action the complete and firm closure of the glottis††. Applied externally to the skin, or taken into the stomach, it occasions giddiness, pain and weight in the head, obscurity of sight, and ringing in the ears‡‡.

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* Mayo, Phys., pp. 120, 131. Mayo, Path., 336. Müller, Phys., 556. Robert Lee, Cyclopæd. Pract. Med. vol. iv. p. 383.

† Mayo, Phys., p. 63.

‡ Müller, p. 328.

§ Müller, p. 330.

‖ Müller, ibid.

¶ Brodie, Phil. Trans., c. ii. p. 390.

** Davy on Nit. Ox., p. 472. Christison on Poisons, 3rd ed., 745.

†† Ibid.

‡‡ Collard de Martigni, Archives, 211. Christison, 2nd ed., pp. 703–706.

Inhaled by the breath, it is well known to produce serious and alarming symptoms, varying as the gas may be more or less diluted. The following experiments show its effects when injected into the vessels.

EXPERIMENT I.—*To show the Effect of Carbonic Acid injected into the Veins.*

Two fluid ounces (by measure) of this gas, prepared by the action of diluted hydrochloric acid upon chalk, were collected over water, and thrown slowly, by a syringe, into the external saphæna vein of a strong dog. Almost immediately afterwards the animal exhibited signs of uneasiness, uttered cries of distress, became convulsed, lost its consciousness, and appeared to be dying; it felt, however, the stimulus of cold water when thrown upon it, and quickly recovered upon being removed into the fresh air.

It thus is capable of producing a powerful impression on the system, when thrown into the veins even in a small quantity. Still more marked results ensued when it was introduced into an artery, as was shown in the next experiment.

EXPERIMENT II.—*To show the Effects of Carbonic Acid when thrown into the Carotid Artery.*

The left external carotid artery was exposed in the same dog, and a small tube was introduced into it, a ligature having previously been applied to prevent hemorrhage: a fluid ounce and a half (by measure) of carbonic acid was then thrown in. This was done gently, but it was necessary to discontinue the experiment, in consequence of the animal becoming convulsed and foaming at the mouth. After forty seconds it seemed to recover; but again relapsed, lost all consciousness and power of movement, was quite insensible, and lay as if dead upon the floor. At intervals of a few minutes it was seized with attacks of violent spasms. This alternation of stupor and convulsions continued for four hours, when the animal regained its senses, the power of its limbs, and appeared afterwards to suffer no inconvenience.

M. Nysten considers that the effects witnessed on throwing carbonic acid into the vessels arise from the distension of the right side of the heart; this seems, however, questionable in the experiment just detailed, as the gas was injected slowly in a direction from the heart, and produced other symptoms than those described as arising from the simple admixture of air with venous blood*. This eminent experimentalist certainly errs in considering that carbonic acid is not itself intrinsically poisonous. It cannot be necessary to pause in order to refute this idea, but it is worth while to mention the diversity in its effects: some speak of experiencing a lively sensation of pleasure on respiring it; others, of the sensation of a gentle heat and perspiration; and Sir Humphry Davy said he could answer, from his own experience, that no pain precedes the insensibility occasioned by breathing gases unfitted for supporting life†. In general, however, vertigo, head-ache, accelerated pulse, hurried breathing, palpitation of the heart, tendency to sleep, ending in complete loss of consciousness, with convulsions, mark its effects during life; whilst retention of the warmth of the body, flexibility of the limbs, fluidity and blackness of the blood, characterise after death the bodies of those poisoned by this gas.

If we now turn to those diseases, the leading symptoms of which bear resemblance to the effects of carbonic acid, we find them to be such as prevent the proper arterialization of the blood, emphysema of the lungs, diseases of the heart; or, to be brief, all such as impede respiration, in which cases we find hebetude of mind, torpor of body, inclination to doze, spasmodic respiratory movements, and the tendency to convulsive muscular action. It is not, in truth, novel to refer these symptoms to the accumulation of carbon in the system; but, close as the similarity in many respects undoubtedly is in these instances, the disorder in which we have the nearest resemblance, and which seems as if it were its true prototype, is still the *Opprobrium Medicorum*. We have in the symptoms produced by carbonic acid, the counterpart of those exhibited in epilepsy; no less instantaneous is the attack of this appalling malady, than are the effects of the sudden closure of the glottis by the irritation of the choke damp, or other exposure to fixed air, by persons descending into vats, or breathing the gas given off by fermentation. Plunge an animal into it, or inject it into the veins, and we can at will produce epilepsy with all its terrific features and depressing consequences.

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* Mayo, Phys., p. 72.

† Salmonia, p. 112.

The curious coincidence of the diminished secretion of this acid from the lungs, towards evening, when the natural tendency to sleep comes on; the increase in its quantity at day-break, when epileptic seizures are most likely to occur; the hurried and spasmodic respiration, when it is present in excess, are valid arguments for the belief that it may be an active agent in exciting both healthy and disordered functions.

Carbonic acid acts upon the medulla oblongata, for it annihilates volition and consciousness, which have their seat in this portion of the nervous centres. The medulla oblongata also, be it observed, is the source of the respiratory movements*. How these are called into action we are yet in doubt; that they may be excited primarily and throughout life by the stimulus of carbonic acid, is advanced as a conjecture, which derives abundant support from the analogy of other excretions.

Minute details would here be out of place, or the quantity of this gas, capable of producing injurious consequences, and the peculiarities of individuals rendering them especially liable to its influence, might be entered into. Suffice it, that extremely minute portions of gaseous bodies, as shown in the instance of the odour of musk, or the fragrance of flowers, is enough to produce the most decided effects.

It were tedious to enter into collateral inquiry, or to combat objections which may be advanced against the ideas thus submitted to the Association. It is doubtless extraordinary that an acid should be formed in the blood, and given off, instead of combining with the alkali of the serum. The insensibility of animals confined in nitrogen or hydrogen gases, in which the quantity of carbonic acid nearly equals that by natural respiration, may be otherwise explained; new combinations may form; carburetted hydrogen, for instance, may be generated, which would itself poison the animal; and we should not forget the fact, that the insensibility, occasioned under the circumstances alluded to, is found to be much more easily dissipated than that which arises from the prevention of the escape of carbonic acid from the body.

From this we might pass on to various spasmodic disorders, but it were perhaps premature to say anything further on this head; only one more point shall be noticed in connection with this subject, and that is the resemblance in the effects of narcotic poisons to those arising from carbonic acid. Reflections upon these facts have led me to think that this gas may play an essential part in the phenomena exhibited by narcotics, a class of substances, the operation of which is so little understood, but the action of which is obviously upon the functions of the system, rather than upon the vascularity of its organs. It has long been laid down as a rule, that opium is not to be exhibited when the blood is not properly aërated or decarbonised.

Many experiments have been made by me to ascertain whether any difference existed in the quantity of carbonic acid given off from the system, when under the influence of opium. With this view the quantity eliminated before and after a dose of this drug had been taken, has been repeatedly measured. The experiments were performed by breathing through a solution of pure potassa, and by weighing the result, as well as extricating the carbonic acid acquired. It is unnecessary to enumerate the modifications in the apparatus used, in order completely to separate the watery vapour, to prevent the chloride of calcium employed for this purpose from descending into the potassa and negativing the result, to obviate the escape of minute portions of the solution of potassa on passing the expired air through it; the conclusion arrived at is, that much more carbonic acid is given off simultaneously with the production of the effects of opium. Not only is the number of respirations increased, and thus more is eliminated, but in an equal number of respirations there was found to be an increase of at least one-tenth. The quantity of opium taken was equivalent to a grain and a half of the extract, and the observation was made as soon as the effects (tightness of the forehead, slight sensation of nausea, accelerated pulse, quickened breathing, and general feeling of tranquillity) were perceived. It were easy to show the general likeness of the action of narcotics to those produced by carbonic acid gas; but to connect them with this last-named agent will require further inquiry.

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* Müller, pp. 348, 351, 827, 918.

Allow me now, in conclusion, to state that the ideas expressed in this paper, are submitted with great deference to the Meeting; that they are advanced with the view of calling attention to certain interesting but obscure phenomena, and are forwarded in compliance with the desire of the Association.

15 Welbeck Street, July 1841.

Report on Discussions of Bristol Tides, performed by Mr. BUNT *under the direction of the Rev.* W. WHEWELL, *F.R.S.*

[With Plates 2, 3, 4, 5.]

THE careful and intelligent manner in which Mr. Bunt had conducted those Discussions of the Tides, on which the grants of the British Association in former years had enabled me to employ him, made me very desirous of continuing to profit by his labours, in order to bring, if possible, the ascertained laws of the tides nearer to the observations. With this view I applied at the last meeting for an additional grant of 50*l.*; and have now to report the progress which has been consequently made in our tide discussions. We began by considering the possibility of improving the correction for lunar declination, and the determination of the anterior epoch of the semimenstrual inequality. But it did not appear very probable that any additional discussion of the observations which we had before us would give us any additional accuracy, commensurate with the great labour which must be undergone in making the trial. I was therefore the more ready to follow out a suggestion of Mr. Bunt's, who wrote to me in January last that he had recently determined to try whether he could perceive any effect on the *heights* of high water at Bristol produced by *atmospheric pressure.* He adds, "I accordingly arranged the errors of the calculated heights for 1840 in columns for every two-tenths of an inch of the barometer, observed contemporaneously with the tide."

From a diagram given in his letter, the average effect appeared to be about 15 inches depression of high water to 1 inch rise of mercury in barometer. The consistency of these results leaves no doubt as to the fact of a sensible effect on the heights from this cause. In his letter, he adds, "Some subsequent trials "gave nearly the same result, only a trifle *less* in the depression of high water "for an inch rise of mercury. The specific gravities of mercury and water "being not far (if I recollect right) from this ratio of 14 or 15 to 1, it would "seem that the *total weight* of the compound column of air and water raised "by the force which produces the tide, remains nearly unaffected by the "changes of atmospheric pressure. By introducing this new correction, there-"fore, a very considerable portion of our *Residual Error* is accounted for."

The barometric observations which Mr. Bunt used for finding the effects of atmospheric pressure on the heights of high water at Bristol, were those contained in the register kept at the Bristol Institution, which extended back to a period earlier than the commencement of the tide observations.

As it had appeared that all the other effects of external forces upon the height and time of high water corresponded not to the forces at the moment of observation, but to a state of the forces at an *anterior period*, it occurred as possible that this might also be the case with the effect of the atmospheric pressure upon the height of the tide; and that the correction corresponding to this effect might be most accurately obtained by taking the state of the barometer at some period anterior to the time of high water; for instance, twelve hours or twenty-four hours. If this were the case, we should be able to *predict* the effect of atmospheric pressure upon the tide, a day or half a day previous to the event. As this prospect gave an additional interest to the inquiry, I begged Mr. Bunt to try the comparative results of contemporaneous and anterior epochs of the barometric observation. This he proceeded to do, by arranging various portions of our observations according to the heights of the barometer. The following is the account of the result.

"Bristol, Feb. 18, 1841.

"I send you diagrams of the effects of atmospheric pressure on the heights of high water for every tenth of an inch height of the barometer, from 29·2 or ·3 inches to 30·4 or ·5 inches, for the years 1834, 35, 39; barometer and tide contemporaneous. Also for the year 1834, barometer heights being twenty-four hours anterior to high water. Also for 1839, barometer 29·2, ·3, ·4, ·5 inches to 30·2, ·3, ·45 inches, twelve hours anterior to high water. Also the mean of the three years, giving about 14 inches depression of tide to one inch rise of barometer.

"I have also taken the sums of the residues left after introducing the barometer correction, first, contemporaneously with high water, and secondly, at twenty-four hours anterior to high water, for the first six months of the year 1834, measuring the residue at about every high water. The total residues, in the two cases, were so nearly alike, as to leave it doubtful which epoch should be preferred. The diagram for 1834, made from observations of the barometer twenty-four hours anterior to high water, appears about as good as the one from contemporaneous observations of barometer and tide. The extreme groups, however, for 29·2, ·3, ·4 inches, …… 30·4, ·5, ·6 inches barometer, approximate slightly towards the mean line: the same tendency appears in the double groups 29·2, ·3, ·4, ·5 inches, …… 30·2, ·3, ·4, ·5 inches, for 1839, barometer observed contemporaneously with, and at twelve hours anterior to, high water. Hence I should be disposed to infer, that we do not *improve* the result by going back to an anterior epoch; for I take it for granted that the true epoch is that which shows the greatest amount of elevation and depression of tide corresponding with the least and greatest heights of the barometer; or that which makes the greatest angle of inclination between the line connecting the several points or groups, and the axis.

"There is one peculiarity which I have noticed in these barometrical results, and in others which I obtained in my earlier trials, namely, that the effect produced on the heights when the barometer is at any point below 29·4 inches or 29·5 inches, is always greater than the proportion for the greater heights of the barometer. I imagine this arises from the effect of *wind*, which generally follows a great depression of the barometer, and generally, with us, comes from the S.W.; so that an *additional* elevating cause comes into operation. This, however, is mere conjecture."

I then requested that, instead of arranging the observed heights according to the barometer, he would correct the observed heights for lunar and solar parallax and declination, and investigate the effect of atmospheric pressure on the *residues*; still comparing the contemporaneous and the anterior epochs. The following was the result.

"March 17, 1841.

"I send you the results of comparisons of the residues of height for 1834, 1835 and 1836, with the state of the barometer at different epochs. The heights were calculated carefully by numbers, using what I consider to be my best corrections for lunar and solar parallax and declination, and employing the same corrections in each of the three years. The only correction omitted was that for the diurnal inequality. The residues for 1834 were compared with the barometer contemporaneous, twelve hours anterior, twenty-four hours anterior, twenty-four hours *posterior*, and the extreme groups, with barometer, thirty-six hours anterior; in order to find what progressive changes of form the curves would thus be made to assume. The mean correction for one inch difference in height of barometer having been obtained, the proportional correction was applied to each observed height of high water, and the mean of all the errors (remaining after the barometrical correction) then taken for the whole year. In every instance the *contemporaneous* barometer gives the best correction. Thus in 1834 the mean error remaining, after applying the barometrical correction, is

5·817 inches contemporaneous barometer.
6·085 inches barometer twelve hours anterior,
6·221 inches barometer twenty-four hours anterior,
6·248 inches barometer twenty-four hours *posterior*.

"These two latter epochs, the one *anterior* the other *posterior*, producing nearly equal errors, seem to show (like equal altitudes) that the truth lies midway between them.

"In like manner, the mean residual error for 1835 is

5·277 inches, barometer contemporaneous,
5·421 inches, barometer twelve hours anterior,
5·706 inches, barometer twenty-four hours anterior;

and for 1836 is

6·450 inches, barometer contemporaneous,
6·535 inches, barometer twenty-four hours anterior.

"The introduction of the correction for the contemporaneous barometer reduces the mean error, *previously* remaining, about one-fourth, being as 1 : 0·753, for the whole of the year 1834; and as 1 : 0·705 for the year 1835.

"The mean effect on the tide corresponding to a change of one inch in the mercurial column was carefully obtained, by taking into account the number of observations in each parcel, so as to get the true average. The contemporaneous barometer gives, in every instance (as shown in the diagrams), the greatest result: and in this case also equal differences from the maximum attend the anterior and posterior epochs for 1834—viz. 11 inches tide (instead of 13·4 inches) to one inch of mercury.

"The mean depression of tide corresponding to 1 inch rise of barometer, is

	inches.	
For 1834..........	13·4	(contemporaneous barometer),
1835..........	14·6	(ditto ditto),
1836..........	11·9	(ditto ditto).
Mean....	13·3	for three years."

Thus this last investigation appears to have put a negative upon the supposition that the barometric correction of the height of high water corresponds to an *anterior* epoch; for we cannot doubt the justice of the remark made by Mr. Bunt, that since not only the contemporaneous barometer gives the greatest result, but since also *equal differences* from the maximum attend the epochs anterior and posterior by twenty-four hours, the contemporaneous epoch must be the true one. And thus it appears that the effect of atmospheric pressure on the height of the tide is something local and immediate, not an effect transmitted in a finite time from some other place.

I next wished Mr. Bunt to try how far the correction curves of height for lunar and solar parallax and declination would have been different if the barometric correction had been made *first*, before the heights were arranged for the other corrections. This also he undertook. The following is his communication on the subject.

"April, 1841.

"I send you new correction curves made from the observed heights in 1839, after having *first* cleared them of the effects of the changes of atmospheric pressure, allowing 13½ inches of water to one inch difference in the barometric column. The greatest difference is in the solar declination curve at the hour 6½ of transit. I hardly think this can be entirely owing to the atmospheric correction, but most likely to some difference in the working out of the new lunar corrections, especially that for declinations, with which the solar declination is almost inseparably mixed up in any short series of observations. Indeed I can scarcely see how the effects of the two kinds of declination can be separated, with any certainty, about the hours of 0^h and 6^h transit, except by taking two sets of observations, the one having the moon's declination a maximum, and the other a minimum."

The very small differences between these correction curves in their former shape, and as modified by allowing for the barometric correction, might have been expected, since the barometric correction will, on the whole, compensate itself. The smallness of the differences is, however, evidence of the care and consistency with which our results were formerly obtained.

W. Whewell.

Trinity College, Cambridge, July 1, 1841.

Report on the Discussion of Leith Tide Observations, executed by Mr. D. Ross, *of the Hydrographer's Office, Admiralty, under the direction of the Rev.* W. Whewell.

Although tables of the corrections of the heights and time of high water, due to lunar parallax and declination, have already been obtained for several places, (London, Liverpool, Plymouth, and Bristol) it is still desirable to correct and confirm these results by the discussion of observations made at other places, especially if continued for a considerable series of years. Our methods of discussion and tabulation may admit of improvement, and new features may appear in the new results; with these views I applied at the last meeting of the Association for the sum of 50*l.* to enable Mr. Ross to complete the discussion of a series of tide observations made at Leith, extending from 1827 to 1839 inclusive, and now including 1840. This long series of years is advantageous for the purpose of obtaining the declination correction; since, in consequence of the motion of the moon's nodes, the range of lunar declination and the mean declination is very different in different years; as was stated in my Report on the subject, presented to the Association last year.

The present Report will refer to a new mode of presenting the corrections of the *height* of high water for lunar parallax and declination. It has been shown by me in various memoirs that the correction of the height both for lunar parallax and declination is nearly the same for all the hours of moon's transit. This being the case, the greater part of this correction may be expressed by means of a *table of double entry*; the two arguments being the moon's parallax and declination. Mr. Ross suggested to me the advantage of such a table, and has constructed it from the Leith observations, and it is laid before the Association along with the present Report.

It appears by this table, when separated into the two parts dependent upon parallax and declination, that the parallax correction varies very exactly as the parallax; and that the declination correction applicable to declination 0°, varies very nearly as the square of the declination; results agreeing both with those obtained from the tide observations made at other places, and with the consequences of the equilibrium theory modified; as I have previously shown that it must be, in order to express the results of observation. As I have stated, the principal part of the correction of the height of high water for lunar parallax is constant for all hours of moon's transit. But there is a further term of this correction, though a small one, which goes through a cycle of positive and negative values in the course of a semilunation. This has already appeared in the results of the London, Liverpool, Plymouth, and Bristol observations, and also agrees with the theory above referred to. A like result appears in the results of Leith tides by the discussions now reported, but at first sight with a remarkable difference. At Plymouth it appeared (Ninth Series of Tide Researches, Phil. Trans. 1838), that the correction for parallax is least when the hour of moon's transit is 10^h, and greatest when the hour of moon's transit is 4^h or 5^h; the mean parallax correction when the part depending on the hour of transit disappears, occurs at transit 1^h and 7^h. At Leith, on the contrary, the effect of the parallax is greatest when the transit is about 6^h, least when the transit is 0^h, and the mean value obtains when the transit is about 3^h and 9^h. But this great difference in the results, which at first appears to make the course of this correction nearly opposite at the different places, is, in fact, the result of the difference of the time which the original tide-wave employs in reaching Plymouth and Leith. This correction varies nearly as the sine of the double angle of the moon from the sun, minus a certain epoch. Or to be more exact, instead of the sine we may substitute a circular function, which vanishes, and is positive and negative when the sine is, but which does not exactly follow the law of the sine. If this function be called s, the term of which we are now speaking is, in the Plymouth tables, as $s,\ 2\,\phi - 14^h$; in the Leith tables it is as $s,\ 2\,\phi - 18^h$. The difference of the epochs, 14^h and 18^h, depends on the time of transmission of the tide from Plymouth to Leith. This is further illustrated by remarking that in the results of London observations this term is also represented by $s, 2\,\phi - 18^h$; while the Bristol observations give the term $s,\ 2\,\phi - 15^h$.

The agreement of these results cannot but be considered as decisive evidence of the correctness of the tables which we have obtained, as to their form and general law. And this is the more remarkable when we consider how small are the results in which this coincidence is found. The coefficient of the term now spoken of, is at London 3 inches; at Plymouth it is 1 inch; at Bristol, when the rise and fall is very great, this coefficient is 6 inches; at Leith, by the present discussion, its amount is found to be little more than 1 inch. The smallness of this term also leads us to this inference, that Mr. Ross's table of double entry may be used to obtain the corrections of heights for parallax and declination, almost without a sensible error. The table being obtained from Leith observations, will require a constant multiplier to adapt it to other places.

TABLES.

(1.) Mr. Ross's table of the correction of height for parallax and declination.

(2.) Mr. Ross's table of the difference of the parallax correction from the mean for each hour of transit.

(3.) The mean value of this difference for each hour of transit.

(4.) The mean value of this difference for each 3° of declination showing that the declination correction is nearly as the square of the declination.

(5.) The semimenstrual inequality of height for Leith.

(1.)

Declination Moon's.	54½.	55½.	56½.	57½.	58½.	59½.	60½.	61½.	(4.)
	in.	in.	in.	in.	in.	in.	in.	in.	in.
0° – 3°	– 5·2	– 1·6	+ 2·3	+ 6·4	+ 8·7	+ 11·4	+ 17·5	+ 19·3	+ 4·2
3 – 6	– 5·6	– 1·5	+ 2·7	+ 8·8	+ 9·7	+ 12·2	+ 16·4	+ 20·4	+ 4·5
6 – 9	– 6·4	– 1·7	+ 1·4	+ 5·1	+ 9·5	+ 12·3	+ 15·0	+ 19·1	+ 3·6
9 – 12	– 6·7	– 3·2	+ 0·5	+ 4·1	+ 8·4	+ 11·0	+ 14·8	+ 16·3	+ 2·5
12 – 15	– 7·6	– 4·0	– 0·8	+ 3·0	+ 6·4	+ 10·2	+ 12·4	+ 16·3	+ 1·3
15 – 18	– 9·2	– 6·2	– 3·8	– 0·8	+ 4·1	+ 7·8	+ 11·2	+ 14·3	– 0·9
18 – 21	– 11·0	– 9·0	– 3·4	– 1·8	+ 3·4	+ 5·8	+ 9·1	+ 10·5	– 2·7
21 – 24	– 11·5	– 8·8	– 5·7	– 0·6	+ 2·1	+ 7·2	+ 10·1	+ 9·0	– 2·9
24 – 27	– 12·3	– 10·1	– 6·0	– 2·2	+ 0·3	+ 4·7	+ 8·7	+ 7·0	– 4·4
27 – 29	– 15·0	– 12·4	– 8·6	– 4·8	+ 0·7	+ 2·3	+ 6·4	+ 8·4	– 6·0

(2.)

									(3.)
0 – 30	– 1·7	– 2·0	– 1·2	– 0·4	– 2·9	+ 0·4	0	+ 0·5	– 1·6
1 – 30	– 1·1	– 0·5	– 2·2	– 2·1	– 1·0	– 1·0	– 0·4	– 1·9	– 1·3
2 – 30	+ 0·3	– 0·7	– 1·6	– 1·1	0	– 0·7	+ 0·5		– 0·6
3 – 30	+ 1·0	+ 1·1	+ 0·1	– 0·2	– 1·2	– 0·6	+ 0·9		+ 0·2
4 – 30	+ 1·1	+ 1·3	+ 0·9	+ 0·9	+ 0·6	+ 0·3			+ 1·0
5 – 30	+ 1·1	+ 1·5	+ 1·0	+ 1·8	+ 0·8	+ 0·2			+ 1·2
6 – 30	+ 0·8	+ 1·8	+ 1·9	+ 1·1	+ 1·3	+ 0·3			+ 1·4
7 – 30	+ 1·3	+ 1·1	+ 0·4	– 0·2	+ 0·6	+ 0·9			+ 0·6
8 – 30	+ 0·2	+ 0·3	0	+ 0·6	– 0·6	– 0·2	– 1·7		+ 0·1
9 – 30	– 0·3	– 0·8	+ 0·1	+ 0·1	0	+ 0·1	– 0·3		– 0·2
10 – 30	– 0·9	– 1·8	– 0·7	– 1·5	+ 0·2	– 0·2	– 0·8	0	– 0·9
11 – 30	– 1·8	– 2·5	– 0·4	– 1·1	– 0·8	+ 0·1	– 0·5	+ 0·5	– 1·3

(5.) Semimenstrual Lines.

	0–30	1–30	2–30	3–30	4–30	5–30	6–30	7–30	8–30	9–30	10–30	11–30
1827	16 2	15 6¼	14 8¾	13 10¼	13 2½	12 9½	12 11¾	13 10½	14 9	15 6½	16 0½	16 3
1828	16 4¾	15 11	15 0¾	14 2¼	13 5	12 11½	13 1½	14 1	15 0	15 9¾	16 5	16 7½
1829	16 3½	15 11	14 11¾	14 2	13 2½	12 9½	13 1½	13 11	14 9¾	15 8¼	16 1¼	16 5¼
1830	16 3½	15 8¾	14 10½	14 0¼	13 1½	12 9¼	13 1½	13 10¾	14 9½	15 7½	16 2½	16 5½
1831	16 5¾	15 9¾	15 0¾	14 2¼	13 4½	12 11½	13 1	13 11¼	14 9	15 8¾	16 4	16 6½
1832	16 1½	15 8½	14 10	13 11	13 1¼	12 9	12 11¼	13 9¾	14 7¾	15 5	16 0¼	16 3¼
1833	15 11¾	15 7½	14 9½	13 11	13 1¾	12 9½	13 0	13 9¾	14 8¾	15 5¼	15 11¾	16 2
1834	16 1	15 7	14 10½	14 0¼	13 1	12 7½	12 10¾	13 8¼	14 8	15 6	16 0	16 3½
1835	16 0½	15 5¼	14 8¾	13 9½	12 11½	12 6¾	12 10¼	13 8¼	14 8½	15 7¼	16 1¾	16 2¾
1836	15 10¾	15 4	14 7¼	13 10	13 0¼	12 5¼	12 11	13 8¼	14 6¼	15 4¾	16 0	16 1¾
1837	15 9¾	15 3	14 5¾	13 6¾	12 8½	12 2½	12 7	13 4½	14 6	15 3½	15 10	16 1
1838	15 8¾	15 2¼	14 6¼	13 6½	12 8¾	12 2	12 5¾	13 2½	14 3¼	15 3¼	15 9½	15 10½
1839	15 7½	15 2	14 4¾	13 7¼	12 7	12 2½	12 5¾	13 4½	14 3	15 0¾	15 8½	15 10½
1840	15 8¼	15 4	14 7¼	13 8½	12 9¾	12 5½	12 8¼	13 4	14 4	15 2	15 8¼	15 10¼

Upon the working of Whewell's Anemometer at Plymouth during the past year. *By* W. S. Harris, *Esq., F.R.S.*

My last Report on this instrument contained an account of certain improvements in the mechanism and mode of fixing found by experience necessary to its perfect employment. I have now the satisfaction of bringing under the notice of the Physical Section a series of observations, continued for a whole year; from which has been laid down, by the inventor's method, a graphic delineation or type of the wind during this time, and extending from July 1840 to July 1841*. It will be seen by this chart now before us, that we have, to a great extent, realized Mr. Whewell's happy thought, namely, that of obtaining a sort of type of the winds for a given place, so as eventually to arrive at the general annual movement of the air. The mean result of the observations now before us agrees nearly with that arrived at by the observations made by Mr. Southwood, with the same instrument, and printed in the Eighth Report of the Association. It shows in this place (Plymouth) an annual movement of the air from the S.S.E. toward the N.N.W. nearly. It is not a little interesting to observe the daily march of the wind, as indicated by the daily register of the instrument. We find, for example, certain tourbillons or great disturbances occurring here and there, which seem to interfere with what might probably, in more settled latitudes, be a constant and regular movement of the air, as in the trade winds; yet, upon the whole, the progress of such a regular current is traceable, notwithstanding these interferences; and the movement of the air is found to be by this chart from the southerly to the northerly points of the compass. It does not seem requisite, for our present purpose, to attempt more than a very summary generalization; without therefore obtaining, by a strictly geometrical method, the resultant magnitude and direction for each month, and from these again the resultant magnitude and direction of the whole, as done in my former Report, it will perhaps suffice to pass a line immediately through the whole series of types, in such way as to obtain by the eye alone the final resultant. Such a line will evidently pass from the S.S.E. to the N.N.W. points of the compass, or very nearly. If now we associate this fact with the result obtained from the hourly meteorological observations at the Dockyard, we are entitled to say, so far as our experiments extend, that there is an annual movement of the atmosphere in this latitude toward the north, under a mean pressure of 29·900 inches nearly, taken at the level of the sea, and a mean temperature of 52° Fahr. The complete and satisfactory working of the anemometer, now that it has undergone certain amendments, found by experience desirable, leads me to hope that its use will be persevered in by observers in meteorology, since the principle on which it has been founded is undoubtedly very perfect and satisfactory. I do not, after a very critical examination, and experience in the use of the instrument, see any difficulty whatever in respect to its mechanism which may not be easily conquered; and it only now remains to find what are the actual numerical values of its indications; that is to say, having been enabled to trace an annual movement of the air in the direction above stated, we should at the same time be enabled to determine the rate of the motion. This would seem at first sight a sufficiently difficult matter. We may hope, however, to arrive at something like a fair approximation to such information, by the following mode of experiment, now in progress.

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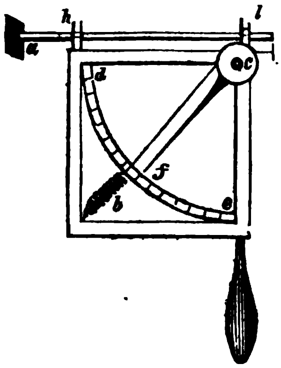
* The delineation here referred to was exhibited in the Section-room, in a frame 12 feet high by 6 feet wide.

With a view of determining the amount of pressure as observable by exposing surfaces varying in dimensions to the aërial current, the portable gauge represented in the annexed figure has been successfully applied. A brass quadrant *d e*, being set in a frame of brass and divided in the usual way, a pressure plate *a* is so applied on the top of the frame as to act by a rod *h l*, and a silk line over intervening pulleys on the spiral spring *b*; the pulley *c* fixed in the centre of the quadrant carries the index *c f*, which will rise on the graduated arc in proportion to the pressure, the amount of this pressure in terms of a standard of weight being known by experiment, that is, by placing different weights on the extremity of the rod held in a vertical position, and observing the corresponding degrees on the arc. If Lind's gauge be employed as a standard, we may readily examine the pressures corresponding to various pressure plates, and thus discover whether the same pressure on a unit of area is shown by different sized plates. This being determined, we are in a state to employ plates of different dimensions according to the violence of the wind, and hence readily compare the pressure with the velocity more easily.



To find the velocity by experiment, a cork stuck round with capacious feathers is made to travel over a fine wire of a given length by the force of the wind; the cork is set on a common writing quill bushed with a small brass plate at each end, and by which the whole is supported on the wire, fine holes being drilled through the brass plates for receiving it. This contrivance is extremely light, and will fly along the wire with the velocity of the wind for a given distance, or very nearly so. It is in fact throwing, as it were, a log-line upon the air. Observers may now compare the pressures, corresponding to certain velocities, and to the descent of the pencil on the anemometer; and thus its indications are reducible by experiment to terms of absolute value, when a sufficient number of observations have been made and tabulated.

Report of a Committee, consisting of Sir J. W. F. HERSCHEL, *Bart., Mr.* WHEWELL, *the Very Rev. the* DEAN OF ELY, *Prof.* LLOYD, *and Lieut.-Col.* SABINE, *appointed for the purpose of superintending the scientific co-operation of the British Association in the system of Simultaneous Observations in Terrestrial Magnetism and Meteorology.*

YOUR Committee, referring to their last Report for the history of the magnetic operations in progress up to the date of that Report, have to state, in continuation, that the magnetic observatory at St. Helena was finished, and the instruments established, in August 1840,—at Toronto in September,—and at Van Diemen's Land in October of the same year. The observatory at the Cape of Good Hope also was completed and in activity at the commencement of March in the current year, delays having occurred in its completion, which, though productive of great uneasiness and distress to its officer in superintendence, Lieut. Eardley Wilmot, could in no way be attributed to any want of exertion, or to any negligence on his part. From each of these stations returns have been regularly received since their respective dates of completion. Previous to this, there have been received returns of seven months of observation in a temporary observatory at Toronto, and of six at St. Helena. All the observations, as soon as received, have been regularly transmitted to Prof. Lloyd, and after examination by him, handed over to Col. Sabine, under whose superintendence, assisted by Lieut. Riddell—the state of whose health, unfortunately, has compelled his return from Toronto—their publication will take place, Government having, on the application of the Royal Society, taken upon themselves this additional expense. In consequence of this arrangement, the reduction and printing of the observations are now in progress. The portable observatories of the *Erebus* and *Terror* were put up at Kerguelen's Land, and also at Van Diemen's Land. At the former station, the May and June terms were observed—at the latter, those of August and September 1840. During the stay of the expedition at these stations, the magnetometers were observed *hourly*; and the regular work of the observatory at the latter station, under the direction of Lieut. Kay, has been begun, and will be continued on this doubly-laborious plan of hourly intervals for the ordinary observations; while on the term-days, all the three magnetometers will be observed at the same instants of time, at intervals of 2½ minutes,—the means of confronting this vast increase of labour being supplied by the Colonial Government, as administered by that ever-active and zealous friend of science, Sir J. Franklin. And in addition to this, and for the sake of multiplying occasions of observing the correspondence of magnetic perturbations with auroral discharges, one hour out of every 24—viz. from 1h. 50m. P.M. to 2h. 50m. P.M., Göttingen mean time, commencing from January 1, 1841—will be occupied with observations of the magnetometers, at 2½ minutes' interval, in this order, viz. bifilar, declination; vertical force, declination; bifilar, declination, V, D, B, D, &c. It is to be hoped that some of the European observatories will, at least occasionally, furnish observations in correspondence with these.

The reduction and publication of the observations made at the Van Diemen's Land observatory and by Captain Ross's expedition have also, at the request of the Admiralty and with the consent of the Master General of the Ordnance, been placed under the superintendence of Lieut.-Colonel Sabine.

The first Report of the Director of the Madras Observatory (Lieut. Ludlow), and the first month's observations, have been received. It commenced regular observation on the 1st of January 1841.

The private observatory established at Mukerston in Scotland, by the munificence of Lieut.-General Sir Thomas Macdougal Brisbane, has been completed in instruments, and has commenced observation. In addition to the terms, a portion of the usual daily routine of magnetical and meteorological observations will be kept up at this observatory.

Of the foreign European observatories, Brussels (M. Quetelet), Prague (Herr Kreil), and Milan (Sig. Carlini), have regularly forwarded the term-observations for each month to the Royal Society. The Cadiz observatory has been completed in instruments, and its director, M. Montojo, has personally visited Dublin, to receive Prof. Lloyd's instructions in the process of observation. In consequence of an application made to the Belgian Government by the Royal Society, through Lord Palmerston, the establishment of the Brussels observatory has been provided with the assistance necessary to carry out the complete system of observation recommended by the Royal Society.

From Breslau a letter has been received from M. Boguslawski, dated July 3, giving an account of the progress of that establishment, the instruments for which, it will be recollected, were supplied by this Association. Annexed to this letter are the projected term-observations for August and November 1840. It will be necessary to provide expressly for the final disposal of the returns which will arrive from this quarter.

The Council of the Royal Society had devoted a sum of money from their Wollaston Donation Fund for the purchase of a set of instruments for the magnetic observatory, the erection of which at Alten, near Hammerfest, was, at the date of the last Report of this Committee, under consideration by the Norwegian Government. Some difficulties have presented themselves since, which will probably prevent, or materially modify, the accomplishment of this object, or substitute for observations at Hammerfest a series to be made at Christiania, under the direction of M. Hansteen. Be this as it may, this liberality on the part of the Royal Society was highly opportune, inasmuch as it left disposable the grant placed at the disposal of your Committee at the last meeting.

Under the head of "Observatories entirely new," your Committee have to announce the projected establishment of a private one at Havañah, by Drs. Belot and Jörg, which from the geographical position of the station will be extremely valuable.

The term-days of May and August 1840 have been both remarkable for the magnitude of the disturbances. Mr. Riddell has undertaken to have all the observations of these two days projected in curves, which will probably be completed and laid before the Association at this meeting.

By a letter received from M. Kupffer, dated 25th March 1841, it appears that the observations in the magnetic observatory at St. Petersburgh commenced on the 1st of January, and at Caterinenbourg on the 10th of March. In the course of the summer they will be commenced at Helsingfors; and at Tiflis, in all probability, during the autumn. The total number of magnetical observatories which may at present be reckoned on as brought, or about to be brought, into effective co-operation, is fifty-one.

On the 12th of November 1840, the *Erebus* and *Terror* left Hobart Town for their first summer's research in the Antarctic Circle, leaving Lieut. Kay, with Messrs. Dayman and Scott as his assistants, in charge of the observatory at Ross Bank. During the temporary sojourns of the expedition on land or ice, the observations will be made on the same enlarged plan as at Hobart Town. Their first term will, in all probability, have been observed in November at the Auckland Islands. The first point to be determined would be, the point of maximum intensity in the southern hemisphere, the meridian of which had been indicated by the daily observations in the passage from Kerguelen's Land to Van Diemen's Land, leaving only its latitude undecided. Having accomplished this, they will proceed, as rapidly as circumstances will permit, to seek and determine the position of the point of vertical dip. The observations at sea, it should be mentioned, succeed to the fullest extent of the most sanguine expectations; so much so, that the three magnetic elements are daily observed on board, with a precision perfectly adequate to the actual demands of magnetic science.

Intimately connected with a system of simultaneous observations at central stations, is the subject of magnetic surveys of the surrounding districts. It is only by reference to such central stations as zero points, that itinerant determinations can be divested of the influence of temporary and casual magnetic derangement, and brought into comparability with the general magnetic system of the globe. It is, therefore, of the utmost importance that every advantage should be taken of the present fortunate conjuncture to secure the *whole* benefit of the simultaneous system, and to extend it from points over districts. Itinerant observations, made on a concerted system, and precisely simultaneous with those at the fixed observatories, will acquire (if accurately made) all the value of stationary ones, becoming, *ipso facto*, and at each instant, reducible to a central station. Moreover, by this means alone can the amount of station-error for each element, at the central stations themselves, be ascertained; by which is meant, all that part of each resolved element of the magnetic force, which, not being participated in by the surrounding district, must be attributed to attractions merely local and accidental. Without such surveys, executed at *some* epoch, this error cannot be even approximately fixed. If executed at this particular time, not only will it be settled with precision, but the surveys will become an integrant part of the whole mass of observation, and be rendered infinitely more valuable as data for future reference, than they could possibly be, if deferred till after the conclusion of the stationary observations.

Under this impression, it is highly gratifying to your Committee to be enabled to announce, that one very important survey of this kind—that of the British possessions in North America—has, on the application of the President and Council of the Royal Society, been undertaken by Government, on a scale both liberal and satisfactory—a young, ardent, and instructed officer, Lieut. Younghusband, R.A., qualified for the work by a residence and practice in magnetic observation in the observatory at Toronto, having been added to the establishment of that observatory, with a view to this especial service, for three years, with a non-commissioned officer as his assistant, furnished with every instrumental requisite, a liberal provision for travelling expenses, and with the promise of gratuitous canoe conveyance, from the Hudson's Bay Company, in the territories belonging to them. In anticipation, moreover, of a similar magnetic survey of South Africa, though as yet no formal application for such a survey has been made, the Master-General of the Ordnance has ordered a second officer of Artillery (Lieut. Clerk) to be attached to the observatory at the Cape of Good Hope.

As regards this important department of the general subject, your Committee have further to notice the magnetic survey of British Guiana, which has been undertaken by Mr. Schomburgk, one of the Commissioners appointed by Government to determine the boundaries of that province, and who, on an application to that effect on the part of the Royal Geographical Society, has been supplied by your Committee, from the grants placed at their disposal, with a transportable magnetometer (to be returned when the work is complete)—the receipt of which is acknowledged by a letter from the Secretary of that body, dated Feb. 10, 1841. Nor must your Committee pass in silence the instructions given, and the instruments supplied by Government, (in duplicate, and with complete instructions for the use of each,)—also on application from the President and Council of the Royal Society,—to the African Expedition, for the purpose of observation in the course of that expedition. From the scientific zeal which distinguishes many of the officers of that expedition,—scarcely inferior to that zeal in the cause of humanity which has led them to enter on so perilous a service,—results highly valuable to magnetic science may be expected. The transportable magnetometer being one of their instruments, observations on term-days during some months, corresponding with those in Guiana, will probably be obtained, and thus localities, otherwise of high interest, and remote from any central station, will be bound together.

Mr. Caldecott, Astronomer to His Highness the Rajah of Travancore, whose magnetical observatory, completely furnished in instruments, commenced its operations on the May term-day of the present year, has also declared his intention to undertake the magnetic survey of Southern India; while in the north of that empire we may expect, from the zeal and energy of Capt. Boileau, that no exertions on his part will be wanting to secure a similar advantage in that quarter.

In all such surveys it is highly desirable that a regular and concerted system of observation should be followed, and above all things, that the condition of exact conformity to the hours of simultaneous observation should be adhered to; as well as that, if practicable, all determinations of important points, intended to be made with particular care and exactness, should be performed on the term-days; which object, by the exercise of a certain degree of forethought in laying out the plan of travel, may doubtless be accomplished in the great majority of instances.

Connected with, and of importance to, the practical working of the observatories, your Committee beg leave to call attention to Prof. Lloyd's supplementary paper, "On the Mutual Action of permanent Magnets," in which those conditions of equilibrium are investigated which it is possible to satisfy, independent of the relative forces of the magnets. In this paper, independent of the practical utility of the rules laid down for the disposal of the magnets in fixed observatories, the demonstration of the extreme minuteness of the possible amount of uncompensated error arising from mutual attraction cannot but be regarded as highly satisfactory.

Finally, your Committee have to report on their employment of the grant of *50l.*, placed at their disposal at the last meeting, which they have expended on the purchase of a transportable magnetometer, by Meyerstein, of Göttingen, for the Guiana survey. Some improvements, not contemplated originally, having been introduced into the construction of this instrument, its total cost, including freight, somewhat exceeded this sum, leaving a balance of *12l. 2s.* against the Committee, for which it is necessary they should pray an indemnity, as well as a continuance of the grant of money placed at their disposal.

Signed, on the part of the Committee,
J. F. W. HERSCHEL.

Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord.

WITH reference to the resolutions passed at Glasgow, viz. "That a Committee, consisting of Major Sabine and Sir J. Herschel, be requested to provide two actinometers, for observations on the intensity of Solar Radiation, to be made by Prof. Agassiz, at considerable heights in the Alps, and that the sum of 10*l.* be placed at the disposal of the Committee for that purpose;"—"That Major Sabine be requested to provide a good mountain barometer and a thermometer, for the assistance of Mr. M'Cord in his meteorological observations—the sum of 20*l.* to be placed at the disposal of Major Sabine for the purpose"—Col. Sabine reported, that M. Agassiz had been supplied with two actinometers, at the cost of 10*l.*; and that a good mountain barometer was forwarded to Mr. M'Cord early in the spring of this year, having been previously compared with the standard barometer of the Royal Society; and that a thermometer was not sent, because Mr. Newman informed Col. Sabine that an excellent standard thermometer had been ordered by Mr. M'Cord himself, and had been forwarded to him. The cost of the mountain barometer was 6*l.* 12*s.* 6*d.*

Report of a Committee, consisting of Sir J. HERSCHEL *only, to superintend the reduction of Meteorological Observations.—July* 1841.

DURING the last year several series of observations for the years 1837 and 1838, as well as a few for 1839, have dropped in, and every endeavour has been made to procure copies of such as were still wanting from stations whence there was reason to presume that observations were forwarded but had never come to hand. These endeavours, in several instances, have proved successful, and in consequence the list of stations at which available series, having some degree of consecutiveness and connexion, can be made out, is considerably enlarged. The whole number of series in hand, and under reduction at present, amounts to upwards of three hundred, being the results of observations at about seventy stations.

In the year elapsed, Mr. Birt has been employed in tabulating, reducing, projecting, and comparing the barometric curves, a process which has been completed for the whole of the American group (which is by far the most numerous and consecutive) for the years 1835, 1836, 1837, and for March 1838, comprising eighty-eight series, made at the following twenty-eight stations, viz.—

Quebec.
Montreal.
Gardiner.
Burlington.
William's College.
Albany.
Boston.
Providence, R. I.
Newhaven.
Middletown.
Western Reserve College.
Flushing.
New York.
Baltimore.
Cincinnati.
Natchez.
Washington.
St. Louis.
Nassau (Bahamas), on shore.
Bahamas, at sea.
St. Catherine's Island.
Magnetic Island.
Gulf of Guayaquil.
Realejo.
Conchagua.
San Blas.
Ohreala.
Norfolk Sound.

One term also has been reduced and projected (June 1836) for each of the other groups, comprising seventeen series, at the same number of stations, viz.—

London.
Oxford.
Halifax.
Limerick.
Markree.
Brussels.
Hanover.
Geneva.
Turin.
Gibraltar.
Cadiz.
Mauritius.
Dadoopoor.
Bangalore.
Feldhausen, C.G.H.
R. Observatory, C.G.H.
Bathurst.

making in all 105 series reduced and projected.

The tabulated results of these reductions, and their projected curves, accompany this Report for the inspection of the Meeting. The curves are purposely projected on a large scale (too large for publication) to afford room for a minute examination and analysis of their several inequalities, with a view to the possibility of tracing the progress of subordinate undulations or of cross waves; and each has been made by Mr. Birt the subject of particular and careful discussion, the results of which he has embodied in the form of notes on the several terms. Many of these contain remarks of much interest, especially that on the December term of 1836, which fortunately comprises the ascending branches of the barometer curves during a remarkable storm, as well as others, which however must be reserved for the final report of your Committee, which it may be confidently stated will be ready for presenting at the next Meeting.

Meanwhile the annexed letters from Mr. Birt will serve to give the Meeting somewhat more than a general idea of the direction which the inquiry is taking, and contain some suggestions relative to a system of concerted observation excellently well adapted to the tracing of atmospheric waves across a tract of country, to which, as well as to his offer to undertake the necessary correspondence, your Committee desires to direct the especial attention of the Meeting. (Signed) J. F. W. Herschel.

"Metropolitan Literary and Scientific Institution, June 1, 1841.

"Dear Sir,—I exceedingly regret that I have been unable to forward you the packet containing the projections, &c. of the American observations until so long after the time mentioned in my last. I was extremely anxious not to omit any point that suggested itself in carefully looking over the projections and tables, and having completed this, I hope the packet will reach you in sufficient time to enable you to draw up the report for the Meeting without inconvenience.

"The remarks I have to offer I have thrown in the form of notes to each sheet of the projections. In these notes I have taken very little, if any, notice of the curves south of the United States, the Bahamas, &c. I may however remark here, that the curves at the Bahamas generally differ from those of the United States; and as they are situated near the northern border of the torrid zone this difference is remarkable and interesting, as it indicates different systems of oscillation peculiar to the zones. Numerous observations from the Bahamas, and the West India islands generally, would be highly interesting.

"One point which I have glanced at in the notes appears to me interesting and worthy of attention in future observations and discussions of this kind, namely, the appearance of the diurnal oscillation when the extent of oscillation at the station is small, for instance under 0·1 inches. Generally as the oscillation increases the diurnal oscillation becomes obscured.

"With respect to the tables and projections, I have very carefully examined them, and I am not conscious of any errors existing; the reductions I have carefully verified in every instance, and the amount of error in the projections is not greater than ·0005 in the readings of the barometric altitudes; this amount of error arises from hygrometric causes.

"With respect to the increase of oscillation, as mentioned in the concluding remarks to the notes on the projections, it appears that the stations from which observations have hitherto been obtained are too few to derive correct conclusions relative to it. Probably, on one or two occasions that may be fixed on for future observations, a number of gentlemen may undertake a series of observations of the barometer, having especially this object in view, once or twice, who might not wish to continue such observations at stated periods. Our universities and academies, and most of, if not all, our provincial institutions, would probably join in this object, and by appointing a day sufficiently remote, many gentlemen who would thus engage in the work would have an opportunity of communicating with their friends, and thus a sufficient number of stations well scattered in different and suitable parts of the country might be obtained. It appears, however, that in order effectually to obtain the object in view, it would be desirable to modify in some degree the observations as they have hitherto been conducted; for, in order to obtain the whole extent of oscillation at any station, it would be *necessary to obtain a complete depression and elevation of the barometric curve.* Thus a time would be fixed on for a simultaneous commencement of the observations at all the stations, say 6 A.M.; but the termination of the observations would depend on the attainment of the elevation or depression of the curve, as the case might be; so that if the barometer was falling at the commencement of the observations, they would terminate when the greatest altitude had been obtained; three or four hours' observation after this point had been observed, would probably be sufficient to indicate the change in the character of the curve. By thus conducting the observations the extent of oscillation at each station would be distinctly obtained, as the lowest and highest points of the barometer would have been observed. Perhaps you will have the kindness to give this subject your consideration, and should it appear to you worth the trouble, I shall be most happy to undertake the management of a correspondence relative to it. "I have the honour to be, dear Sir,

"Yours very respectfully,

"W. R. BIRT."

"Metropolitan Literary and Scientific Institution, July 14, 1841.

"DEAR SIR,—I have very carefully examined the curves obtained in the British Isles, also those in Europe, and have embodied the results of this examination in the accompanying notes and tables.

"The striking difference between the atmospheric affections in the British Isles and those of Europe, is highly interesting; also the difference in the lengths of the undulations observed at the European stations, the western stations exhibiting the longest. On this point, however, I apprehend the observations are not sufficiently numerous to allow of the slightest conjecture being entertained, with the exception that there might have existed several centres of oscillation, the entire systems extending over comparatively small areas, similar to those indicated by the American observations, I believe, of September 1837. "I remain, dear Sir, yours very respectfully,

"W. R. BIRT."

Report of a Committee, consisting of Sir J. HERSCHEL, *Mr.* WHEWELL, *and Mr.* BAILY, *for revising the Nomenclature of the Stars.*

As regards the collection of synonyms, the detection of errors originating in mistakes of entry, copying, printing, or calculation, and their rectification, and the restriction within their just boundaries of the existing constellations, the work of your Committee has been progressive. Owing, however, to the unfortunate accident which has recently befallen one of its members, by whom this department of the work had been especially taken in hand, no precise report at this time can be made of the progress made.

As regards the revision and redistribution of the southern constellations, a catalogue has in the first place been prepared of all stars within the circle of

70° S.P.D. down to the fifth magnitude, with their present actual magnitudes as determined by a series of observations made expressly for that purpose; which catalogue is now in course of printing and publication by the Royal Astronomical Society. With the magnitudes of this catalogue a chart has been constructed, of which several copies have been made. These have been employed for the purpose of grouping the stars in various ways (without regard to existing constellations), and with reference only to forming among themselves the most compact and striking groups which their distribution in the heavens admits, and which the correctness obtained in the magnitudes has now for the first time rendered practicable. After trying many systems, and arranging the groups in a great variety of ways, your Committee have at length agreed on adopting, as the boundaries of the new regions into which they propose distributing the southern stars, only arcs of meridians and parallels of declination for a given epoch; thus including each region within a quadrilateral rectangular figure, whose angular points being tabulated in right ascension and declination, may be treated as artificial stars, and thus brought up by the usual tables of precession to any other epoch, their situation among the stars being unchanged. Thus it will become a mere matter of inspection of a catalogue arranged for the original epoch (which they propose to be that of the Royal Astronomical Society's forthcoming new Catalogue), which region any given star shall belong to.

Proceeding then to assign more particularly the limits of the several regions, they have succeeded in forming an arrangement in which (subject to such revision and modifications as may arise between this and their final report) they feel disposed to rest. Meanwhile, however, as it is of great importance that whatever system they may finally adopt should have the sanction of the astronomical world in general, it has been thought advisable in the first instance to lay before the public an outline of the general plan, together with a reduced sketch of the proposed regions (subject to such revision), with a view to making more generally known its principles, and assembling around it, in the event of its approval, that body of support and assent, of which, as an innovation, it must stand in need. This has accordingly been done in a paper read by one of the members of your Committee to the Astronomical Society, and (with the catalogue above-mentioned) now in course of publication. This being largely distributed among astronomers by the printing an extra number of copies, will, it is expected, lead to the final maturation and reception of the plan. [It was hoped that the printing of this paper, and the accompanying engraving, would be far enough advanced to have enabled copies to be distributed at the present Meeting of the Association; but this not being the case, proof-sheets of the paper and of the reduced skeleton chart are, at all events, annexed to this Report for inspection and perusal by such members as may wish it.]

As respects the nomenclature of the new regions, the Committee are at present engaged in considering it; but some principles, which will probably influence their recommendation when the subject is sufficiently advanced for that step, are stated in the paper already alluded to, which will appear in the forthcoming volume of the Transactions of the Royal Astronomical Society.

But the same necessity (grounded on the incorrectness of magnitudes as laid down in all existing charts) exists for a revision of the northern as well as southern stars in this respect. It therefore becomes worthy of consideration whether a similar plan may not advantageously be carried into execution in both hemispheres; and as, at all events, the actual state of the celestial charts in both is such as to admit of great improvement from an assemblage of more correct photometric data, a general review of *all* the stars down to the fifth magnitude, with this especial object in view, has been undertaken by one of the members of the Committee, conducted on the same plan, the principle of which is explained in the paper alluded to. This review is already in a considerably advanced state, and should circumstances and weather favour will probably be completed before the next Meeting.

In its progress it has required the aid of skeleton charts, prepared by laying down all the stars by dots from planispheres of received authenticity, and sketching in the existing constellations. As the preparation of such skeletons, which require to be very neatly and correctly executed, consumes a vast deal of time and is very troublesome, they, as well as the southern charts above alluded to (thirteen charts in all), have been procured to be executed by Mr. Arrowsmith, which has caused an outlay to the amount of 17*l.* 19*s.* 6*d.*, leaving disposable out of the original grant the sum of 32*l.* 0*s.* 6*d.*, and which the Committee consider will be required for their future proceedings.

(Signed on the part of the Committee) J. F. W. Herschel.

Report of a Committee appointed at the Glasgow Meeting of the British Association in September 1840, *for obtaining Instruments and Registers to record shocks of Earthquakes in Scotland and Ireland.*

It is proper to explain at the outset of this Report, that it narrates only what has been done by the three individual members of the Committee resident in Scotland. It was found by those members impossible to communicate with their associates in Ireland in any trials for ascertaining the instruments adapted to the object in view. So also, in regard to the localities in Ireland and Scotland, where these instruments should be placed, no advantage was anticipated from a correspondence between the members of the Committee in each country respectively, as it was exclusively those connected with, and resident in, the country who knew the localities where earthquake shocks were most frequent, and where intelligent and careful observers could be found.

The members of the Committee in Scotland had several meetings in the beginning of winter to consider some new forms of instruments fitted to register the shocks commonly felt in that part of the island. Several instruments of different forms had previously been constructed and fixed at Comrie in Perthshire, but they were found not sufficiently sensitive to indicate more than a small proportion of the shocks felt in that district.

After a good deal of consideration and a number of trials, two kinds of instruments, out of several which suggested themselves, were in the first instance resolved on. The one kind was on the principle of the *common* pendulum, the other on that of the *inverted* pendulum, or watchmaker's noddy. One instrument was made on the first-mentioned principle, and two on the second. The construction and dimensions of these will now be shortly described.

1. *Common Pendulum Seismometer.*—The pendulum is thirty-nine inches in length from its point of suspension to its lower extremity. At its lower extremity there is a piece of soft chalk in the form of a pencil, which, as the pendulum vibrates, makes a marking on a concave piece of wood painted black, and forming the segment of a sphere with a radius of thirty-nine inches. This segment has white circular lines painted on it parallel with its circumference, and one inch apart from each other. It has also the cardinal points of the compass marked on it. Near the lower end of the pendulum there is a leaden ball of about four or five pounds weight, which is perforated through the middle, so as to admit the pendulum through it. The chalk pencil

presses on the wooden board by a small leaden weight resting on its upper end, inside of a metal tube containing the pencil.

Three wooden rods are fixed to this spherical segment, on its outer edge, at equal distances, and unite above the basis, so as to form a point of suspension for the pendulum.

The instrument is fixed by three feet to the floor of a room, and, with the help of adjusting screws, the chalk is brought to the centre of the concave segment which is to be marked by its vibrations. The concentric circles, which are marked 1, 2, 3, &c., from the centre of the segment, indicate the number of inches that the lower extremity of the pendulum is thrown from the centre; and the cardinal points show the direction from or to which the shock has proceeded.

2. *The Inverted Pendulum Seismometer.*—(1.) The smallest of the instruments made on this principle has a pendulum thirty-nine inches long, and is fixed into a brass socket at its lower end. The connexion between the pendulum and the socket consists of a strong elastic wire, which, by means of a pinching screw, can be either raised or depressed in the socket, so as to increase or diminish the length and sensibility of the pendulum. There is a leaden ball near the top of the pendulum from three to four pounds in weight: it has a hole through its centre so as to allow the pendulum rod to pass freely through it, and it can be fixed at any part of the rod by means of a pinching screw. At the upper extremity of the pendulum there is a soft lead pencil, which rests on an elastic wire contained in a brass tube. The pencil is thus pressed against a white surface of paper, forming the segment of a sphere, having a radius of thirty-nine inches. The paper is pasted on a piece of copper beaten into the proper shape. This copper segment rests on four upright iron rods which are fixed into the base of the instrument. The base consists of four corresponding flat iron bars, which cross in the middle, and support at that point the socket above described, to which the elastic wire of the pendulum is fixed.

There are on the white segment of this instrument concentric lines in red ink, an inch apart, and numbered from the centre, so as to indicate the number of inches that the pendulum is by any shock thrown off its centre. There are also on this segment, as on that of all the instruments, points of the compass to indicate the directions of the shocks.

The instrument is fixed firmly to the floor of the room where it is set. By means of three adjusting screws, which affect the socket, the upper extremity of the pendulum is brought to the centre of the segment to be marked by it.

Any further description of this instrument is rendered unnecessary in consequence of a paper by Professor Forbes, published lately in the Transactions of the Royal Society of Edinburgh, where the mechanism and mathematical properties of it are very clearly pointed out.

(2.) The other instrument constructed on this principle has a pendulum ten feet eight inches in length. The spherical segment, on which the vibrations of its point are intended to be marked, is not, as in the instrument just described, supported on upright rods fixed to its base, but is suspended over the pendulum by a strong hold-fast of iron fixed into a wall. In other respects, the mechanical construction of this instrument is much the same as that of the former one.

The above instruments were sent to Comrie, a small town in Perthshire, where shocks have been very frequent during the last fifty years, and where the earthquake of October 1839 was felt more strongly than in any other part of Scotland. They were given in charge to Mr. Peter Macfarlane, Postmaster at Comrie, a very intelligent person, who had been assiduous in marking down all the shocks which had occurred since October 1839, and who had himself contrived and constructed several ingenious instruments for indicating the shocks.

The three instruments were erected in Comrie and the immediate neighbourhood. The largest of those on the principle of the inverted pendulum is in the town of Comrie, and is fixed inside the steeple of the parish church. The other instrument on the same principle is at Comrie House, situated about a quarter of a mile to the north of Comrie, and taken care of by Colonel Simpson, who resides there. The remaining instrument is at a place called Garriechrow, close to Cluan Hill, about two miles west of Comrie, and is under the immediate charge of the overseer of Sir David Dundas, Bart., of Duneira.

These instruments were erected a few days before the 1st of January 1841. They have been affected only twice, viz. on the 10th and 22nd of March 1841. On the first occasion both of the inverted pendulums had their upper extremities thrown to the west half an inch, where they remained till examined. On the other occasion they were again thrown to the west, but scarcely half an inch. The simple pendulum at Garriechrow has not been affected, and is thought to be not sufficiently sensitive.

The following inferences seem deducible from the way in which the instruments were affected on these two occasions:—(1.) There was, on both occasions, a sudden horizontal movement of the ground where both instruments were placed, indicated by the extremities of them being thrown off their centres. (2.) This horizontal movement, on both occasions, was towards the east. (3.) The amount of this displacement of the ground was, on the first occasion, half an inch; on the second, less than half an inch.

This last-mentioned inference was confirmed by the feelings of those who perceived both shocks, as they considered that the first was the most severe, though neither was nearly half so severe as the shock of October 1839.

Mr. Macfarlane states, however, that on both occasions there was a movement of the earth's crust not indicated by the instruments. He alludes to a *vertical* movement that was sensibly felt, and which on the last occasion was indicated by one of his own instruments.

This circumstance has been alluded to, to show the propriety of having instruments of a different kind from the above. Several have occurred to members of the Committee calculated for vertical movements; and these movements it is of some consequence to have marked and measured, as it is believed they are always produced at Comrie when a shock occurs, and even in cases when there may be little or no horizontal movement.

It is also to be observed, that there is strong reason to believe that the Comrie shocks emanate from a particular spot, the exact position of which can only be ascertained by a number of instruments placed around the supposed locality.

It is hoped, therefore, that the Association will continue the appointment of a Committee, and give a renewed grant of money for procuring instruments and registers. From what has been said, it must be evident that the object which was last year thought worthy of being prosecuted cannot be properly attained without a greater number of instruments, and some of them calculated to indicate vertical movements of the ground. It is also necessary that they should be much more sensitive than those now used; for, though there were only two shocks indicated by the instruments, Mr. Macfarlane reports, that from the 1st January 1841, when they were in operation, to the 1st July, there were no less than twenty-seven shocks distinctly felt at Comrie.

It is unnecessary to refer, in this Report, to the reasons which induced the Association last year to have a regular register of the earthquake shocks occurring in Scotland. The light which such a register is calculated to throw on this dark and important subject is self-evident. The Committee would only add, that the value of such a register is now greatly enhanced by its appearing that in other countries similar registers are kept, which will afford data for comparing the phænomena as exhibited in different parts of the earth's crust respectively, and ascertaining whether, and to what extent, they are connected. In the volume of the Transactions of the Royal Academy of Turin, lately published, there will be found a part of the register kept at St. Jean de Maurienne from the 19th of December 1838, to April 1840, which partly embraces the period comprehended in the Comrie register.

In urging the continuance of the Committee, and of means to enable them to prosecute the object entrusted to them, it may not be out of place to observe, that great additional interest attaches to it from the opinion entertained by several persons who have attended to the subject, that the earthquake shocks of this, and perhaps of other non-volcanic countries, are connected with the state of the atmosphere, and more particularly with electrical agencies. To test the accuracy of this opinion it would be desirable to have some meteorological instruments at Comrie, and accurate registers of their indications kept. It is unnecessary to say that this opinion, if proved to be accurate, would open up new and most important views as to the nature and situation of the forces which are concerned in the production of earthquakes.

If the British Association be still desirous, as it is hoped it will be, of having inquiries prosecuted on this subject, it is recommended that a separate Committee should be appointed for Scotland, where the shocks appear to be more frequent than in any other part of the United Kingdom, and that the Committee should consist of Lord Greenock, Sir John Robison, Professor Jameson, Professor Traill, Professor Christison, Professor Forbes, Thomas Jameson Torrie, Esq., and David Milne, Esq.

With regard to the amount of the grant, it is thought that it certainly should not be *less* than what was appropriated last year, viz. 20*l.*

(Signed) GREENOCK,
DAVID MILNE.

Edinburgh, 10 York Place, 27th July, 1841.

MY DEAR SIR,—I sent you some days ago a Report on the earthquake instruments and registers which have been established at Comrie by the Committee of the British Association.

As a supplement to that Report I now beg to inform you, that on Sunday evening, the 25th inst., there were two earthquake shocks felt at Comrie, by both of which all the instruments set there were moved. Mr. Macfarlane reports, that the seismometer in Comrie parish-church had its point thrown half an inch to the west, which indicated, therefore, a horizontal movement of the earth towards the east. An instrument of my own there also indicated an upward movement to the extent of half an inch.

These results, as they strengthen the recommendation in the Report, that the Committee therein suggested should be appointed, and a sum of money given, I hope you will communicate to the Association.

Yours very truly, DAVID MILNE.

Extract from a Letter from J. BRYCE, *Esq., one of the Members of the Committee, to* D. MILNE, *Esq., dated Maghera Glebe-House, County of Londonderry, July* 21, 1841.

DEAR SIR,—Since the Glasgow Meeting there appeared in the Irish newspapers three notices of earthquakes having occurred; one in the county of

Wexford and two on the North coast. I lost no time in examining into the authenticity of these, and I state to you the result merely, without troubling you with the detail of evidence—there were in reality no earthquakes, the effects of sudden squalls were mistaken for those of earthquakes. I did not personally collect the evidence, but by letter from a great many most intelligent, accurate and trustworthy persons, on whom I fully depend.

You are already in possession of the evidence furnished by Mr. Patterson respecting the Innishowen earthquake, about two years ago. It occurred in a district composed of granite and slate rocks, and I have no doubt of there having been a movement of the ground such as was described.

I am, dear Sir, yours faithfully, J. BRYCE, Jun.

Report of the Committee for making Experiments on the Preservation of Vegetative Powers in Seeds.

In order to carry out the objects of this Committee, it was deemed advisable to draw up a series of suggestions for experiments, and to give them an extensive circulation. The annexed document has accordingly been printed, at a cost of 1*l.* 14*s.*, and will be distributed at the present meeting.

The Committee has yet effected but little in the way of direct experiment. An application was made to the Trustees of the British Museum for permission to make experiments on various seeds obtained from the Egyptian catacombs. The Trustees have liberally granted permission to their officers to select such seeds as could be spared for the purpose. Dr. Daubeny has also made a selection of seeds from the old herbaria at Oxford. The specimens thus obtained have been submitted to experiment, and the results will be reported as soon as a sufficient number of data are collected to lead to any general conclusions.

To provide for the expenses incidental to these experiments, the Committee recommend that the grant of 10*l.* made last year should be renewed.

H. E. STRICKLAND, *Secretary to the Committee.*

Suggestions for Experiments on the Conservation of Vegetative Powers in Seeds.—These Experiments are intended to determine the following questions:—

1. What is the longest period during which the seeds of any plant under any circumstances can retain their vegetative powers?

2. What is the extent of this period in each of the natural orders, genera and species of plants? and how far is it a *distinctive* character of such groups?

3. How far is the extent of this period dependent on the apparent characters of the seed; such as size, hardness of covering, hardness of internal substance, oiliness, mucilage, &c.?

4. What are the circumstances of situation, temperature, dryness, seclusion from the atmosphere, &c. most favourable to the preservation of seeds?

To answer these questions satisfactorily will require the accumulation of a large mass of facts; and although there are many difficulties in the way of such an investigation, and many years may elapse before it can be brought to maturity, yet it is desirable that the British Association should commence the collection of materials for the purpose. It is proposed then to invite botanists and others to undertake the following series of experiments, and to communicate the results to the British Association.

These experiments are either Retrospective or Prospective.

A. Retrospective Experiments.

1. By collecting samples of ancient soils from situations where vegetation cannot now take place, and by exposing these soils to air, light, warmth, and moisture, to ascertain whether any, and if any, what, species of plants spontaneously vegetate in them.

N.B.—Care must of course be taken that no seeds obtain admittance into these soils from external sources,—such as the air or water introduced to promote vegetation.

These ancient soils are either *natural* or *artificial* deposits.

The *natural* deposits belong either to *past* geological periods or to the *recent* period.

a. The deposits of past periods are either secondary or tertiary.

N.B.—There seems every reason to believe that the age even of the latest of these deposits is far beyond the maximum period through which vegetative powers can be preserved; yet as many accounts are recorded of seeds vegetating spontaneously in such soils, it would be well to set these statements at rest by actual experiment.

In such experiments, state the formation, and describe the geological phænomena of the locality, together with the depth from the present surface at which the soil was obtained.

b. Natural deposits of the recent period may be classed as follows:—

Alluvions of rivers.
Tidal warp land.
Shell marl.
Peat.
Surface-soil buried by landslips.
Ditto ditto by volcanic eruptions.

In these cases, state the nature of the soil, the depth from the surface, &c.; and especially endeavour to obtain an approximate date to each specimen of soil, by comparing its depth from the surface with the present rate of deposition, or by consulting historical records. It would be well to submit to experiment a series of samples of soil taken from successive depths at the same locality.

c. Artificial deposits are as follows:—

Ancient tumuli.
Ancient encampments.
The soil beneath the foundation of buildings.
The soil with which graves, wells, mines, or other excavations have been filled up.
Ridges of arable land, &c.

In these cases, state, as before, the depth from the surface, and ascertain from historical sources the approximate age of the deposit.

2. By trying experiments on actual seeds which exist in artificial repositories. These are,—

Seeds in old herbaria and botanical museums.
Seeds obtained from mummies, funereal urns, at Pompeii, Herculaneum, &c.
Dated samples of old seeds from nurserymen and seedsmen.

In these cases, state the circumstances in which the seeds have been preserved, and their date as nearly as it can be ascertained.

B. Prospective Experiments.

In this department of the inquiry, it is proposed to form deposits of various kinds of seeds under different conditions, and to place a portion of them at successive periods under circumstances calculated to excite the process of vegetation. In the case of certain species or families of plants, it would perhaps require many centuries to determine the limit of their vegetative powers, yet it is probable that a very few years would suffice to fix the maximum duration of the greater number, and that many interesting results might thus be obtained even by the present generation of botanists. It is proposed then to form a collection of the seeds of a great variety of plants, (including, wherever it is possible, at least one species of every genus,) and to pack them up (carefully labelled) either alone, or mixed with various materials, as sand, sawdust, melted wax or tallow, clay, garden mould, &c. in various vessels, as glass bottles, porous earthen jars, wooden boxes, metal cases, &c., placed in various situations, as under-ground, in cellars, dry apartments, &c. At certain intervals increasing in extent,—say at first every two years, then every five, every ten, and, at the lapse of a century, every twenty years, a small number (say twenty) of each kind of seed, from each combination of circumstances, to be taken out and sown in an appropriate soil and temperature, and an exact register kept of the number of seeds which vegetate compared with those which fail.

Should it appear desirable for this project to be carried out by the British Association, they might most effectually accomplish it by committing a collection of seeds, formed on the above plan, to some qualified person, whose duty it should be, in consideration of a small annual stipend, to take charge of them, and at stated periods to select portions for experiment, keeping an accurate register of the results.

In this manner it is believed, that in regard to the large majority of plants, the limit of their vegetative durability would be determined in a very few years, and that a large mass of vulgar errors on this subject, which now pass current for facts, would be cancelled and exploded.

N.B.—The most effectual way of exciting vegetation in seeds of great antiquity, is to sow them in a hot-bed, under glass, and in a light soil moderately watered.

On Inquiries into the Races of Man, by DR. HODGKIN.

DR. HODGKIN read a Report, from which the following are extracts, respecting the drawing up, printing, and circulation of Queries concerning the human race, for the use of travellers and others.

"The list of Queries, as presented in a printed form to the Meeting last year, has undergone revision and correction, and may now be regarded as comprising Queries relating to every branch of the subject with sufficient minuteness to suggest inquiry and invite reports from travellers of different tastes and acquirements. An edition of the Queries in their present form has been printed off, and copies have already been extensively circulated, but there has not been sufficient time to admit of the return of replies from those parts of the globe from which they are the most to be desired.

"Copies have been furnished to the British Museum, to the Royal Geographical Society, and to other scientific bodies, foreign as well as British. Considerable pains have been taken to place them in the hands of intelligent travellers about to visit those quarters in which natives exist, but of whom imperfect accounts have hitherto reached us, and whose altered condition, or extermination, is likely in a short time to deprive us of the possibility of obtaining a knowledge of what they have been, unless it be promptly collected. On the occasion of the fitting out of a well-appointed expedition to ascend the Niger, and thus penetrate into the interior of Africa, copies were furnished to the commanders of the vessels, and to the intelligent naturalists and draftsmen who formed a part of their suite. Very recently, intelligence has reached this country, that an expedition, well equipped on all points, is about to proceed, for the purposes of scientific inquiry, from the southern shores of the Red Sea, in a south-westerly direction, with the hope of reaching the Cape by a somewhat circuitous route. Should this expedition happily succeed in its undertaking, it will necessarily have to pass through the midst of nations and tribes of Africans, of whom a more extensive as well as correct knowledge is, notwithstanding all the research hitherto employed, still essentially necessary for our possessing anything like an accurate view of the characters and distribution of the African races, and for our arriving at any well-grounded conclusions concerning the modes, directions, periods, and circumstances of their diffusion over the continent, and of the influence which they have reciprocally excited upon each other by fusion, by reduction of numbers, or by the change of their physical and social condition. Several copies of the Queries are now in the way of transmission to the gentlemen composing that expedition. They are accompanied by some observations suggested by circumstances peculiar to the mission, and the regions through which it is designed to pass.

"Sir George Simpson, the Governor of the Hudson Bay Company's territory, having a few months since left this country with the intention of crossing the North American Continent, from Canada to Vancouver, of visiting the Russian settlements, and of passing over land by Kamtschatka to Petersburgh, the opportunity was not lost to endeavour to increase the interest which he already has felt in the character and situation of the several tribes with whom his official situation necessarily brings him into contact. Copies of the Queries were furnished, not only for the governor's own use and that of Dr. Rowand, an intelligent medical man, partly of Indian descent, who was expected to accompany the governor in his entire route, but also for such residents at the Company's settlements as might be judged likely to turn them to good account. Several copies have likewise been addressed to correspondents already settled in remote situations. Although it is to be feared that many of the copies which have been thus distributed may fail to procure from those who receive them the direct replies which they call for, it is not too much to hope, that, from various quarters, detailed series of answers may be received, and found in no small degree to contribute to the interest and advantage of the sittings of this Section at future Meetings of the Association. It is perhaps not too much to anticipate, that in this way the diffusion of these Queries may not only serve the too-much neglected cause of the science of Ethnography, but indirectly promote a practically benevolent interest in some of the feeble and perishing branches of the human family. Even in those cases in which direct replies are not obtained, some good may not unreasonably be looked for from the mere fact of their directing the attention of the reader to a great variety of points connected with the scattered families of man. In many minds they may originate trains of thought, and excite interest, inquiry, and investigation; and even with those who have no means of making investigations of their own, they may yet serve to create an appetite for information of a kind which at present is, in general, but little appreciated, and consequently but sparingly supplied. Nevertheless, the interests of science, of our country, and of humanity at large, are essentially connected with this subject. When it is considered that other countries, which have immeasurably less direct interest in the condition of the uncivilized sections of the human race, and who, as respects wrongs to be atoned for, and advantages to be reaped, may be regarded as all but foreign to it, are notwithstanding pursuing it with zeal, it certainly behoves us, for the credit of our country, to endeavour to diffuse a more extensive and operative interest in relation to it."

Dr. Hodgkin stated that sufficient time had not elapsed for the return of answers from distant countries. Some interesting information had, however, been elicited by them from a gentleman who had lately travelled in Texas, where he had observed the remnants of the ancient Mexicans. He pointed out some of the national reasons which call for exertion on the part of Englishmen, and related some of the labours of foreigners, and more especially of the Ethnographical Society of Paris, of Dr. Dieffenbach, R. H. Schomburgk, and other Germans, and those of the government as well as of individuals of the United States, and gave a description of the gallery of North American Indian curiosities and portraits collected and exhibited with great expense and pains by George Catlin, whose work on the Indians of North America he announced as nearly ready for publication. Dr. Hodgkin dwelt on the importance of Ethnological researches, and on the absolute necessity for promptly pursuing the work if anything valuable and satisfactory is to be accomplished; seeing that the races in question are not only changing character, but rapidly disappearing.

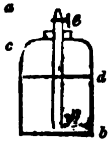
"It is this threatened extinction of races of men who have been either wholly neglected or very imperfectly studied, which seems to bring this subject peculiarly within the province of this Section of the British Association. Why should not the varieties of our own species receive as much attention as those of inferior animals, however remarkable or rare they may be? Has the extinction of a variety of man ever excited equal attention with that which has been paid to the loss of the dodo? Or has the diminution of any tribe of Aborigines received a proportionate share of solicitude with that which has been given, not to the *extinction* of a species, but to its *disappearance from a particular locality*, as in the case of the 'cock of the woods,' from the northern parts of this island? Successful attempts have been made to restore these animals to their ancient haunts; and it has even been contemplated to restore the long-lost wild boar to the list of British wild animals. A rare variety of the ox or the dog is preserved with unremitting care, and often at great expense, from generation to generation; and a rare specimen in any department of natural history is sought with unremitting perseverance, preserved with pains, and purchased at an almost unlimited expense. It is not to disparage the zeal which is justly devoted to any of the various branches to which these objects may belong, that these observations are offered; they are merely made for the purpose of urging that man himself, even as an object of Natural History, may receive a degree of attention proportioned to the exalted rank which he holds amongst the works of his Creator. A great variety of interests are united in ascertaining the mode in which man, as the highest of animals, has been diffused over the surface of the globe."

Dr. Hodgkin concluded by urging, as practical means for advancing the cause of Ethnological investigation, first, the bringing home, for the purpose of being studied themselves, as well as of being made the subjects of suitable education, well-selected aboriginal youths, and especially such as have had an opportunity of acquiring knowledge, and exhibiting ability in missionary or other native schools. This plan, which need not equal in expense what is often done for other objects of zoology and for botany, might be facilitated by the union of individual contributors. Secondly, rendering personal and pecuniary aid to the Aborigines' Protection Society, the objects of which were neither of a party nor of a sectarian character, but were solely directed to the preservation, amelioration, and study of the feeble races of mankind, amongst which those related to British colonies occupied the chief place. Dr. Hodgkin observed, that the objects pursued by this Society furnished subject-matter not merely for the Zoological, but also for the Medical and the Statistical Sections. Details of the plans, operations and present state of the Aborigines' Protection Society may be obtained from its publications, which are to be had at the Society's Office, 17 Beaufort Buildings, Strand. The Queries regarding the races of man, to which this report refers, will be found in another part of this volume.

Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable Expense of such Experiments, and to draw up Directions for Observers in such circumstances.

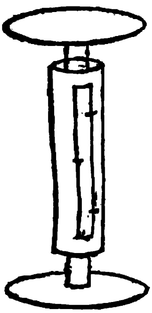
ALTHOUGH much valuable information might be obtained by means of aërostatic observation, the pecuniary outlay which would be required for this purpose is so considerable, that the Committee do not at present recommend any application of the funds for this object, much less any attempt to induce Her Majesty's Government to incur the expense, until the plan has been more fully matured. But experience derived from ascents made under ordinary circumstances, as opportunity may offer, would be desirable, both as regards the kind of instruments, the mode of using them, the special points to be attended to, the degree of concordance to be expected in results obtained at different times, places, and states of the atmosphere. The principal objects required are, to determine the progression of temperature, and the law of the distribution of vapour, in ascending from the surface of the earth to the upper regions of the atmosphere. There can be no doubt that, in a perfectly dry and undisturbed atmosphere of air, the temperature would be found to decrease as we ascend, as the density decreases; and that this must be its normal state to which, amongst all its fluctuations, it must tend. The decrease of density, however, is liable to the action of various disturbing causes, the principal of which are the evolution of heat by the local condensation of vapour, and its absorption by the evaporation of clouds. The law of the decrease would most probably be elicited from the mean results of a great number of careful observations, in which a compensation of such disturbances would take place; but it cannot be expected that it should be apparent in such a limited series as can be comprised in a single ascent. It is probable that the temperature observed at short intervals, instead of presenting a regularly decreasing progression, would exhibit great irregularities; as, for instance, that it would be found in a calm to decrease to a certain point, then become steady for a time, or possibly rise, especially upon passing through a cloud, or upon entering a current flowing in a different direction from that upon the surface: or, if the condensation of vapour were taking place from the action of a cold wind flowing into, and mingling with, a saturated atmosphere, instead of arising from the regular decrease of temperature due to the decreased density, a sudden and great depression would be found. The observer's attention should be particularly directed to the influence of clouds or changes of currents upon the thermometer. Mr. Green has found that the isothermal planes are parallel, or nearly so, to the earth's surface, so that the aëronaut knows generally, even although the earth may be intercepted by a cloud, when he is crossing a chain of hills; or at least the upper surface of the clouds generally follows in a great measure the configuration of the earth. "The upper surface of the clouds, upon occasions when they overspread the earth at a moderate elevation, seems to accommodate itself to all the variations of form in the subjacent soil." Mr. Green has also found, that it is usual to ascend to a greater elevation to experience the same reduction of temperature when the earth is overspread with clouds than in a cloudless sky. According to Mr. Monck Mason, a singular relation is found to exist between the formation or precipitation of rain, and the condition of the sky above the clouds which contain it. "Whenever from a sky completely overcast with clouds rain is falling, a similar range of clouds invariably exists in a certain elevation above, whereby the rays of the sun are intercepted from the layer below; and on the contrary, whenever, with the same apparent condition of the sky below, rain is altogether or generally absent, a clear expanse of firmament, with a sun unobstructed by clouds, is the prevailing character of the space immediately above: thus leaving it a determinate fact, that when rain is pouring from clouds overspreading the earth, the rays of the sun are not operating upon the clouds in question; while, on the other hand, rain does not fall from such clouds when the rays of the sun are unobstructedly falling upon the upper surface." According to the same authority, and in conformity with the opinion of Mr. Green, it appears that, in this country, whatever may be the direction of the wind below, in the higher regions, that is, generally within 10,000 feet above the surface of the earth, the direction of the wind is invariably from some point between the north and west. It appears from Mr. Green's observations, that "the variation experienced in the course of the wind during the progress of the ascent was accompanied by a corresponding alteration in the intensity of its rate, the current which at the commencement was gentle becoming strong as it took another direction, and *vice versâ*." These important facts in Meteorology could not have been ascertained by any observations made at the surface of the earth, and afford strong evidence of the advantages which might result to science from well-planned aëronautic expeditions. With regard to the atmosphere of vapour, it is probable that it tends to the maintenance of an analogous but very different progression of density and temperature, from below upwards, to that of the gaseous atmosphere; but being constrained to diffuse itself through the latter, it is controlled and regulated by the temperature into which it is thus forced. Thus the elasticity with which it will rise from the surface of the earth, in the act of evaporation, will be determined by the temperature of some upper stratum of the air, at which it will become condensed, the force at which point will limit by its reaction that of the evaporating surface. Between these two points, therefore, the dew-point will probably be found to be steady, or to decline by a very slow progression. After passing through the cloud, it may be expected that the dew-point will fall at once several degrees; the elasticity of the vapour on the upper side being probably governed and determined by a new point of condensation in still higher regions, just as the dew-point on the surface of the earth is conceived to be determined by the temperature of the first vapour-plane. This would imply, that while precipitation was taking place on one side of a bed of clouds, rapid evaporation might be going on upon the other. It is also conceivable that these processes of condensation and evaporation may be so adjusted as that they may exactly counteract each other; and the vapour-plane might thus be indicated by no cloud, or possibly by a mere haze; but the dew-point would fall suddenly. To this circumstance the observer's attention should be particularly directed. It is probable that, in ascending to a great height, several vapour-planes might be thus crossed, and the confirmation of the hypothesis would be of importance to science in elucidating the constitution of the atmosphere. It is obvious that, for the purposes just indicated, the observations of the thermometer and dew-point should, if possible, be unremitted during the whole time both of the ascent and descent, and, of course, must be accompanied by simultaneous observations of the barometer: one person's time should therefore be wholly devoted to these objects; and the arrangement should be well considered, by which his labour may be facilitated and his attention kept undistracted. The prevailing forms and structure of the clouds; their internal motions, if any; the number of strata which may be detected, and the number and direction of the currents which their motion may indicate, will also form interesting objects of observation in conjunction with the preceding. Contemporaneous observations will, of course, be made on the earth during the time of the aërostatic voyage, which will possess a greatly-increased interest if circumstances should permit it to take place on the day when hourly meteorological observations are made at all the principal observatories of Europe, according to the plan laid down by Sir J. Herschel. Portions of the air should be brought down, for examination, from the highest elevations; and this may probably be best effected by taking up several glass balloons, or bottles carefully gauged, fitted with stop-cocks, and filled with water. The water should be allowed to run out at the proper station, and the stop-cocks closed. Experiments upon the radiation of heat, by another observer, would also be interesting, although there are probably no known means of instituting them with all the accuracy which could be desired. Observations with Sir J. Herschel's actinometer might be made upon the force of solar radiation at various heights; but the instrument would not be applicable to the measurement of terrestrial radiation. When a delicate thermometer, whose bulb is covered with lamp-black, is placed in the focus of a parabolic reflector, and turned towards the clear sky, even in the day-time, it will radiate a portion of its heat into space; by the same contrivance, the rays of heat proceeding from the earth, or from beds of clouds, would be condensed upon the thermometer, and some estimate formed of their intensity. Observations upon these points at different heights, and at different periods of the day and night, would be instructive, though not of the high importance which would belong to those of the thermometer and hygrometer. To these observations might be added others of great interest upon the electricity of the atmosphere, by dropping wires into clouds, or from stratum to stratum of cloudless air, and examining the nature of the electricity of their extremity by means of a very delicate electroscope: but attractive as these researches may prove, the Committee recommend, that should a series of ascents be undertaken by one or many observers, on no occasion should the observer's attention be distracted by too great a variety of objects; and that our efforts should at first be directed solely to the elucidation of the question of the decrease of temperature, by the acquisition of accurate contemporaneous observations of the barometer and thermometer made at different elevations. It would manifestly be desirable, that while observations of atmospheric temperature and pressure were made in a balloon, two observers, stationed at the extremities of an accurately measured base, and provided with theodolites of the best construction, should by their observations determine the height of the balloon geometrically, at the instants the observations of temperature and pressure were made. This, however, implies a more extensive system of cooperation, and a larger personal and instrumental force, than could probably be assembled. It will, therefore, be best to confine the observations simply to the determination of corresponding temperatures and pressures of the atmosphere. For this purpose nothing more is wanted than a supply of instruments that can be easily used and give accurate results.

Of the Hygrometer.—It is desirable that two hygrometers should be provided, which may be fixed side by side upon the lid of a box, into which they may be contrived to pack. The observer should not only note the temperature of the first appearance of dew, but the temperature at which it again disappears; and while he is waiting for the last observation by one instrument, he may proceed to make a new one with the other. A store of the best æther should be provided, and a convenient dropping-bottle. No disadvantage would arise from the effect of the diminished pressure upon the boiling-point of the æther, if placed in a bottle contrived for the purpose; as thus,
a b the bottle,
c d the level of the æther,
e f a tube fitted tight into the neck, and passing to the bottom of the liquid, furnished with a stop-cock *e*. As the atmospheric pressure diminished upon the aperture of the stop-cock, the pressure of the included vapour would pour out a stream of æther, which might be regulated, and the rapidity of its subsequent evaporation would be a great advantage; but as it is probable that the dryness of some of the upper sections of the atmosphere may be extreme, smaller tubes, filled with condensed sulphurous acid, should be provided, and kept cool in ice, by the dropping of which upon the bulb of the hygrometer extreme cold may be produced. As an additional precaution, a small bright silver capsule and delicate spirit-thermometer may be prepared, by which the dew-point may be observed from the direct evaporation of the acid. Bottles containing a mixture of liquid carbonic acid and æther might perhaps be prepared, which would answer the purpose still more perfectly. As it is extremely desirable that the relation of the cold produced by evaporation from the surface of a wet-bulbed thermometer with the dew-point should be ascertained, and as such an observation would not add much to the trouble of the observer, Dr. Mason's hygrometer, which is a convenient form of the instrument, may be fixed upon a stem upon the box, immediately behind the hygrometers, and the temperatures of the two thermometers may be noted. The freezing of the water in the upper regions will, however, put an end to these observations. The stem which supports the thermometers may also be made to carry a moveable card-board, covered on the outside with gilt paper, so as to screen all the instruments from direct radiant heat.



Of the Barometer.—The only barometer that can be used, and can be *trusted* in observations like those in question, appears to be the Siphon-barometer of Bunten, in Paris (Quay Pelletier, No. 26), or barometers of a similar construction by Robinson, of London. The tubes of Bunten appear to be carefully made; the column of mercury is easily seen; and the slow motion of the verniers, though not so fine as in Robinson's, is more easily managed, a circumstance of some importance in the present instance. The barometers should be new: their scales divided in millimetres only. Some of them have a scale of English inches, which, owing to some mistake about standard temperature, is very erroneous. They should be always kept inverted, except when in actual use. When allowed to hang in the position in which they are used, the mercury in the short tube becomes oxidized, the glass covered with a powder of the oxide, and the capillary depression considerably increased, which renders the instrument useless. In a cistern-barometer, where the level of the mercury cannot be observed, the corrections for a change of level for *small* variations of barometrical pressure are extremely troublesome. For *large* changes of barometrical pressure they must become uncertain in the highest degree. Troughton's mode of determining the lower level is decidedly bad. The cistern-barometers, in which the lower level is determined by contact of a point with the surface of mercury, are good *comparative* or *differential* instruments, but nothing more.

Of the Thermometer.—The best and most convenient thermometers appear to be those made by Greiner, of Berlin, with a paper scale enclosed in an outer tube, or a scale of milk-white glass. The bulbs are exposed, and the scales cannot be injured by immersing the bulbs, or whole instrument in water, or any other liquid, for purposes of comparison. The graduation should extend from −85° Fahr. to about + 100° Fahr. In Gay-Lussac's ascent, the thermometer descended 40° 25″. It is not likely that any observers would ascend much higher than he did, or that they would undertake an ascent when the temperature at the earth's surface was less than 10° C. The thermometers, during the ascent, should be enclosed in bright tin tubes (having an opening through which the scale can be observed), open at both ends, with a round disc of tin at a little distance from the ends, to prevent the effect of radiation. Thermometers thus protected were used at the Cambridge Observatory, and found to answer well. The temperature of the air being already known, one thermometer with a wet bulb will be sufficient to determine the pressure of vapour at a given station.



Directions for Observing.—When the motion of the balloon in a vertical direction appears to be small. 1. Observe the thermometer attached to the barometer. 2. Make the lower edge of the upper ring appear to touch the upper end of the mercurial column. 3. Make the lower edge of the lower ring appear to touch the lower end of column. 4. Observe the thermometer in the tin case for temperature of air, and note the time. 5. Read off the two verniers of the barometer. 6. Observe the psychometer (wet-bulb thermometer) and Daniell's hygrometer. The observations at the surface of the earth should be made in the same order. The observers should avoid as much as possible approaching the thermometer and barometer, in order that they should not influence the temperature. The aëronaut must be instructed in making the contact between the ring and the end of the mercurial column, also in reading a vernier correctly.

Cost of Instruments.

Two of Bunten's barometers, each 4*l.* 8*s.*	£8	16*s.*
Duty, 25 per cent.	2	4
Two thermometers, each 1*l.* 11*s.* 6*d.*	3	3
Duty, 25 per cent.	0	16
Same, to be used with wet bulbs	3	3
Duty, 25 per cent.	0	16
	£18	18*s.*

Tin cases for thermometers, Daniell's hygrometer, &c.

It would be manifestly imprudent to commence operations with only just a sufficient stock of such fragile instruments as barometers and thermometers. Duplicates of every one should be provided. This would make the cost of the instruments amount to about 50*l.* To the above might be added,—a sympezometer, constructed for the purpose, *without* sliding scale,—a maximum and minimum thermometer, about as large as a watch, constructed by Breguet.

(Signed) David Brewster,
J. F. W. Herschel,
J. W. Lubbock,
T. R. Robinson,
Edward Sabine,
W. Whewell,
W. H. Miller.

Report on British Fossil Reptiles. By RICHARD OWEN, *Esq., F.R.S., F.G.S., &c. &c.*

PART II.

THE British Fossil Reptiles described in the first part of this Report presented modifications of their osseous structure, and especially of the vertebral column and locomotive extremities, by which they were especially adapted for a marine life, and hence have been collectively termed *Enaliosauria.* All the numerous species of this family are extinct, and it seems that the genera have ceased to be represented since the deposition of the chalk formations. In the present zoological systems the *Plesiosauri* and *Ichthyosauri* are referrible to the Saurian order of reptiles, as defined by Cuvier; but they offer the most remarkable deviations from the existing types, and constitute links which connect the Reptiles, on the one hand, with Fishes, and, on the other hand, with the cetaceous Mammals.

The present and concluding part of the Report on British Fossil Reptiles contains an account of the remains of the Crocodilian, Dinosaurian, Lacertian, Pterodactylian, Chelonian, Ophidian and Batrachian reptiles.

The most remarkable of the extinct species of the amphibious and terrestrial *Sauria* of England have been discovered and described by Dr. Buckland and Dr. Mantell. Some remains are briefly noticed by Parkinson*, and by the older English observers, as Wooller and Chapman. Cuvier has added to the value of these discoveries by his just observations and comparisons. Some of the British Chelonian fossils have been noticed by Parkinson, Cuvier and Dr. Mantell; but none of the British extinct Ophidians or Batrachians appear to have been hitherto recognized as such.

PLIOSAURUS.

The Enaliosaurs are immediately connected with the Crocodilian reptiles by an extinct genus, represented by species of gigantic size, of which the remains are not unfrequent in the Kimmeridge and Oxford clays. The Reptile in question is essentially a modified *Plesiosaurus,* but its modifications appear to entitle it to be regarded as a distinct genus, which, as it is more closely allied to the true Sauria, I have proposed to call *Pliosaurus*†.

Large, simple, conical teeth, with the enamelled crown traversed by well-defined and abruptly terminated longitudinal or oblique ridges, as in the teeth of the Plesiosaur, have not unfrequently been discovered in the Kimmeridge clay formation. These teeth differ from those of the Plesiosaur in their greater relative thickness as compared with their length, and in the subtrihedral shape of their crown; the outer side is slightly convex, sometimes nearly flat; it is separated from the two other sides by two sharp ridges; these are more convex, and the angle dividing them is often so rounded off that they form a demi-cone, and the shape of the tooth thus approximates very closely to that of the Mosasaur, with which it is equal in size. It may be readily distinguished, however, even when the crown only is preserved, by the ridges which traverse the inner or convex sides, the outer flattened surface alone being smooth; but an entire tooth of the present extinct Reptile presents a long fang, which at once removes it from the acrodont group of lacertine Saurians, and allies it with the thecodont Reptiles, among which it approaches nearest, in the superficial markings of the crown, to the Plesiosaur.

The known parts of the skeleton of the gigantic extinct reptile, to which the teeth in question belong, confirm this approximation; but the vertebræ of the neck are so modified, that the peculiarly elongated proportion of this part of the spine, which characterizes the typical Plesiosaurs, is exchanged for one that much more nearly approaches the opposite condition of the cervical region in the Ichthyosaurs. This abrogation of the main characteristic of the Plesiosaurs, combined with the more crocodilian proportions of the teeth, establishes the claims of the *Pliosaurus* to generic distinction.

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* Organic Remains of a Former World, vol. iii.

† Odontography, Part II., p. 282.

In the collection of Professor Buckland, at Oxford, is preserved a considerable proportion of both the upper and lower jaws of a gigantic specimen of the *Pliosaurus*, from the Kimmeridge clay formation at Market-Raisin. The teeth are arranged in separate sockets, in a close and regular series, along the alveolar borders of the intermaxillary, maxillary and premandibular bones. Twenty-six sockets may be counted on the most perfect side of the upper jaw; but the series is evidently incomplete posteriorly. An interspace, not quite equal to the breadth of a socket, divides the fourth from the fifth tooth, counting backwards, and the jaw is slightly compressed at this interspace; the four anterior teeth, thus marked off, occupy the slightly expanded anterior extremity of the upper jaw, but do not present the excessive size of the corresponding teeth in the Plesiosaur. After the fifth tooth the sockets progressively increase in size to the twelfth tooth, and from the fourteenth they begin gradually to diminish in size, becoming, beyond the twentieth tooth, smaller than those at the fore part of the jaw.

The alveolar septa are narrow, and are thinned off to an edge, which is lower than either the outer or inner walls of the sockets: these walls are equally developed. A line drawn transversely across any of the twelve anterior sockets would be transverse to the jaws, but in the remaining sockets it would incline obliquely from without, inwards and backwards. The transverse diameter of the thirteenth socket is one inch six lines; its antero-posterior diameter is one inch eight lines.

The extent of the alveolar series in both jaws is nearly three feet; the breadth of the palate at the twenty-sixth tooth is nearly one foot; the breadth of the upper jaw at the third tooth is four inches and three lines; the breadth of the socket of that tooth is one inch three lines.

In the lower jaw of the specimen in the Oxford Museum, the posterior extremity of the dental series is complete, but not the anterior one; thirty-five teeth are present in each premandibular bone. The first, from its large size, I conclude to have been received into the slight concavity at the side of the upper jaw, where the diastema separates the fourth and fifth teeth; there are probably, therefore, thirty-eight teeth on each side of the lower jaw. Counting backwards, on this supposition, the teeth begin to diminish in size beyond the fifteenth, and at the posterior extremity of the series the sockets are less than half an inch in diameter: in their close arrangement and position they correspond with those of the upper jaw.

The teeth which are preserved in this magnificent cranial fragment, present the characters above defined. The inserted fangs of most of these teeth are four inches in length; the entire tooth being thus seven inches in length. The ridges which divide the outer from the inner surfaces of the tooth subside at the base of the crown; the fang is smooth; it assumes a subcircular form, gradually expands for about half its length, and then contracts to its termination; but this is always less pointed than in the fully formed teeth of the true Plesiosaur. In the old teeth with the elongated fang, the pulp cavity remains open, as in the Plesiosaurian teeth; it presents at the expanded part of the fang a narrow elliptic transverse section. In a tooth of the present species, six inches and a half in length from the Kimmeridge clay at Shotover, the diameter of the persistent pulp-cavity was thirteen lines. In this tooth the flattened surface is polished, but marked with minute shallow wrinkles; one of the ridged surfaces, which stood at right angles to the preceding, was traversed by eleven well-marked linear ridges of unequal length, separated by smooth interspaces of about three times the breadth of the ridges; the third surface, which formed an acute angle with the smooth outer surface, was traversed by twelve ridges. These ridges, on the inner surface of the tooth, slightly inclined towards the rounded angle, dividing the surfaces; they terminate abruptly; some cease half way from the apex of the crown; about ten are continued to within half an inch of the apex, which is smooth; the two ridges, which divide the flat or smooth side from the ridged surfaces of the tooth, are alone continued to the subacute apex of the tooth.

The teeth of the Pliosaur present varieties of form as well as of size; the rounding off of the angle between the ridged surfaces has been already alluded to; the smooth outer surface is sometimes so convex, that the transverse section of the tooth is more elliptical than triangular. All the teeth of the Pliosaur are slightly bent inwards and backwards; but the smaller posterior teeth are most recurved, and have the sharpest apex; and in the crown of these teeth the ordinary rounded or elliptical form of the cone is most nearly attained; but the distinction of the smooth external surface, and the ridged internal surfaces of the crown of the tooth are retained, and would suffice to characterize any of these teeth if found detached.

The teeth consist of a central body of compact dentine, with a coronal investment of enamel, and a general covering of cement. The dentine is permeated by fine calcigerous tubes, without admixture of medullary canals. The arrangement, division, secondary undulations, and branches of the calcigerous tubes closely correspond with those of the teeth of the Plesiosaur. The germs of the successional teeth in the Pliosaur were developed at the inner side of the basis of the old teeth, but did not penetrate these teeth; the apices of the new teeth make their appearance through foramina situated at the inner side, and generally at the interspaces of the sockets of the old teeth. Here, therefore, as perhaps also in the Pterodactyle, the growing teeth may be included in closed recesses of the osseous substance of the jaw, and emerge through tracts distinct from the sockets of their predecessors, which is an exceptional condition of the reproduction of the teeth in reptiles.

Of the Vertebral Column.—A long neck has been considered to be so peculiarly the distinction of the Plesiosaur, that a species which has this part of the spine shortened and reduced by the flattening of the vertebræ to Ichthyosaurian proportions, may be reasonably regarded as at least subgenerically distinct, especially when the enormous and massive head, to which the abbreviated neck bears a subordinate relationship, is armed with teeth which have just been shown to be as remarkable for their thickness and strength as those of the Plesiosaurus are for their slender and sharp-pointed proportions.

Perhaps there is no example, save the genus *Pliosaurus*, in the whole class of reptiles, living or extinct, which has any of the vertebræ presenting such proportions as those of the following specimen in Dr. Buckland's collection from the Kimmeridge clay of Foxcombe Hill, near Oxford. The breadth of the body of this vertebra is six inches; its depth, or vertical diameter, five inches; while in length, or the diameter corresponding with the axis of the body, it measures only an inch and a half. But cervical vertebræ of similar proportions have been discovered in the Kimmeridge clay near Weymouth, and were described by Mr. Conybeare in the 'Geological Transactions.' The Market-Raisin specimen in the Oxford Museum proves that those peculiarly compressed vertebræ are associated with the well-defined teeth characteristic of the Oxford and Kimmeridge clays, and with jaws of great size, which could only be supported and wielded by a neck as short and strong as in the Cetaceous inhabitants of the sea.

The cervical vertebræ, as they recede from the head, increase in breadth and depth, but retain the same length, as they do throughout the spine in most Saurians, whatever may be their other dimensions. But in the dorsal region of the spine of the Pliosaur, the vertebræ acquire a great increase of length, and there assume the ordinary proportions of Plesiosaurian vertebræ: for example, the first dorsal vertebra of the Market-Raisin specimen, which is four inches three lines in breadth, and four inches in depth, measures nearly three inches in length. The posterior dorsal vertebræ slightly increase in depth, and with the same transverse diameter they present a length of 3 inches 2 lines. The height of one of these vertebræ, including the spinous process, is 11 inches. These proportions are retained at least to the base of the tail. A vertebra from this part, obtained from St. Giles's gravel-pit, near Oxford, and probably washed out of the Kimmeridge clay, measures in length 3 inches; in the breadth of the body, 4 inches 9 lines; in the depth of the same, 4 inches 4 lines.

In the extreme difference which the vertebræ of the neck and those of the rest of the trunk present in regard to their length, the *Pliosaurus* forms a remarkable exception to Saurians in general; for in the true Enaliosaurs, in Crocodiles, in Lizards, whatever other modifications the vertebræ may undergo, or however much they may be expanded in breadth or depth, they maintain great constancy in the length or antero-posterior diameter of the body. The Pterodactyles, or flying-lizards, offer another exception to this rule, and the cervical region is here likewise the seat of the variation; but whereas in the Pliosaur the cervical vertebræ are remarkable for their shortness; in the Pterodactyle they differ from the other vertebræ in their extreme length.

The general structure of the vertebræ of the Pliosaur corresponds closely with that of the Plesiosaur. The osseous texture is compact at the circumference of the vertebræ, and coarsely, but uniformly, cellular in the rest of the bone. The neurapophyses do not become anchylosed to the centrum, nor the ribs to the costal processes. The articular surfaces at each end of the centrum are flat in the cervical, very slightly concave in the dorsal, rather more concave in the caudal vertebræ. The cervical ribs, judging from their articulation with the centrum, must have been unusually strong. The rib on each side of the vertebra was supported on two transverse processes, slightly raised beyond the level of the centrum, occupying two-thirds of its antero-posterior extent, and divided by a deep and well-marked linear fissure. In the anterior cervical vertebræ above described, with a length of 1 inch 9 lines, and a height of centrum of 3 inches 3 lines, the antero-posterior diameter of the constant surfaces was 1 inch 2 lines; their united vertical diameter, 2 inches 2 lines. They occupy a space nearly equi-distant from the upper and lower surfaces of the centrum. At the base of the neck they begin to rise, as in the Plesiosaur, upon the neurapophysis, and are supported, in the dorsal region, upon a single stout transverse process. This is subdepressed, with an oval transverse section, which is rather sharp at the anterior margin. The spinous process of the dorsal vertebræ is nearly straight, compressed laterally; its antero-posterior diameter was 2 inches 8 lines; in a vertebra, measuring in the same diameter 3 inches 2 lines, its height from the base of the neurapophysis was 7 inches. The sides of the centrum are rather rugous near the articular ends, elsewhere smooth and concave, especially in the dorsal vertebræ. The lower surface has the two vascular perforations in the cervical regions; the vertebræ become slightly contracted towards this part in the dorsal region. In the caudal vertebræ the costal process is single, vertically elliptical, and prominent. The non-articular surface of the centrum is not very regular, but is smooth; the lower surface is square-shaped, and nearly flat; its angles are marked by the hæmapophysial surfaces, of which the anterior pair is the largest.

Bones of the Extremities.—The type of construction of the bones of the extremities closely accords with that of the Plesiosaur. The pectoral arch owes its chief strength to a pair of immensely expanded coracoids, having a broad and short entosternal bone on their anterior interspace, and supporting the clavicles, or the acromial productions of the scapulæ.

The femur of the Market-Raisin specimen measures two feet two inches in length, and is thirteen inches broad at its distal end—a bone well fitted to support and wield the strong paddle that must have been mainly instrumental in propelling this carnivorous sea-monster through its native element.

In another femur, measuring thirteen and a half inches across the distal end, the circumference of the proximal end was nearly two feet; the upper half of the bone is cylindrical; it gradually exchanges this for a compressed expanded distal end, which is terminated by a pretty regular convex curve. The texture of the bone is coarsely cellular throughout, being devoid, as in other marine Saurians, of any trace of medullary cavity.

One of the subcircular carpal bones of the Market-Raisin specimen measured five and a half inches across the broadest part, and four and a half across the narrowest, and was two and a half inches in thickness.

The phalanges are short and less compressed than in the Plesiosaurs; flat at the articular extremities, and remarkably contracted in the middle.

Besides the localities affording specimens from which the general description of the bones of the trunk and extremities is taken, and which localities are noticed in that description, remains of the Pliosaur have been discovered in the following localities:—A small cervical vertebra from Shotover, in the Oxford Museum; four dorsal vertebræ, equal in size with the Market-Raisin specimen, from Marcham, also in the Oxford Museum; the vertebra in the Yorkshire Museum*, said to have been found in the gravel of Burn, one mile below Nunnykirk, Northumberland, and noticed in the first edition of Lyell's 'Principles of Geology,' is a posterior cervical of a *Pliosaurus*, and must be presumed to have been accidentally introduced into that recent deposit. The several specimens from these different localities yield strong indications of two distinct species of the present gigantic genus, which connects the Enaliosaurs with the Cœlospondylian Crocodiles. The difference in breadth and height, and especially in the size of the hatchet-bone, or cervical rib, as indicated by the articular surface, appear to be inexplicable, except on the supposition of two distinct species. The difference is continued in the dorsal vertebræ, the transverse processes of which are more compressed, and the non-articular surface more rugous in the Shotover than in the Market-Raisin species. The two forms of femora, on which the species *Plesiosauri grandis* and *trochanterius* are founded in the former part of this Report, are both referable to the genus *Pliosaurus*; but have not as yet been found so associated with vertebræ as to aid, in combination with the vertebral characters, in the definition of the two species. When subsequent discoveries and observations shall have supplied distinct and recognizable characters to the two species of the present very remarkable and interesting annectant genus, the term *brachydeirus*, which I had first proposed for the species represented by the magnificent remains from Market-Raisin*, would be equally applicable to the short-necked gigantic Pliosaur from Shotover, and consequently lose its value as a distinctive appellation.

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* In the Yorkshire Museum there is preserved a humerus of a Pliosaur from the lower part of the Kimmeridge clay deposit at Speaton, which measures thirteen inches in length, and seven inches across the distant end: the femur of the same specimen measured sixteen inches in length.

CROCODILIA.

The remains of species of this order extend from the Eocene tertiary formations as low down as the Oolite and Lias, and offer deviations from the structure of the existing genera and species, which increase in degree and amount as the strata containing the extinct species indicate periods more remote from the present time.

Not any of the species are identical with those now known to exist, and the modifications of the osseous structure, by which the extinct Crocodilians differ both from the present races and from one another, are much greater than any of those by which the skeletons of the existing species differ among themselves. Not only do the form and proportions of the peripheral parts, as of the jaws, the teeth, and the locomotive extremities vary, but the spine, or central axis of the skeleton, offers modifications of the articular surfaces of the component vertebræ which are quite unknown in the Alligators, Crocodiles and Gavials of the present epoch. In these existing species the anterior surface of the vertebral centrum is concave, the posterior convex, except in the atlas and sacrum. But besides this mode of junction, Cuvier has recognized in the Crocodilians of the secondary formations two other types of vertebral structure: in one of these the positions of the ball and socket are reversed; in the other, and more common modification, both articular surfaces of the vertebra are flat or slightly concave. Remains of extinct Crocodilians, exhibiting all the three systems of vertebral articulation, occur in English formations. The extinct species, which agree with the existing Crocodilians in their vertebral characters, will be first described.

a. *With concavo-convex Vertebræ.*

CROCODILUS SPENCERI, Buckland.

'*Crocodile de Sheppy,*' Cuv.

The most recent stratum in which I have met with the remains of extinct Crocodiles in Great Britain is the Eocene deposit called the London clay†. A third cervical vertebra from the Isle of Sheppy, is noticed by Cuvier as being very similar to the corresponding bone in an existing Crocodile, and as having appertained to an individual of probably five feet in length. No other part of this Eocene reptile is noticed in the last edition of the 'Ossemens Fossiles‡.' A fine cranium is preserved in the British Museum; and Dr. Buckland § has figured a smaller but better preserved specimen of the Sheppy Crocodile, in the collection of E. Spencer, Esq. I have examined both these specimens, and have compared them with the skulls of the recent Crocodilians.

In Mr. Spencer's fossil, the end of the snout, including the intermaxillaries and nostrils, is broken off; the tympanic pedicles, pterygoid alæ and occipital tubercle, and the crown of the teeth are also wanting. The principal and most characteristic differences which the *Crocodilus Spenceri* presents in reference to the *Crocodilus biporcatus*, or other existing species of Crocodile or Alligator, are the larger size of the temporal holes as compared with the orbits, the more regular and rapid diminution of the head towards the snout, the straight line of the alveolar tract, and the greater relative length and slenderness of the muzzle, which is evident notwithstanding its imperfect condition. These differential characters are equally manifest in the larger, and in some respects more perfect specimen, of the cranium of this species in the British Museum.

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* Odontography, p. 283.

† Cuvier makes mention of the calcaneum of a Crocodile in the collection of M. G. A. Deluc, said to have been discovered at Brentford in the year 1791, associated with the remains of the Mammoth, Hippopotamus, Rhinoceros and Deer, and which bore incontestable marks of a distinct species. He observes that if this bone had not been transported to its present situation, with the debris of other strata, it would be the most recent of the remains of the genus of Crocodile.—*Loc. cit.*, p. 336, vol. ix.

‡ 8vo, 1836, vol. ix. p. 327.

§ Bridgewater Treatise, vol. i. p. 251, pl. xxv. fig. 1.

Amongst existing Crocodiles, the Bornean species, called *Crocodilus Schlegelii*, most resembles the *Crocodilus Spenceri*. But in the Sheppy Crocodile the posterior smooth surface of the occiput is less concave; its upper boundary line is indented in the middle by the termination of a median longitudinal depression upon the upper surface of the skull, which is not present in the existing species, in which the corresponding surface is flat. The descending process of the basi-occipital, below the articular tubercle, is smoother in the *Crocodilus Spenceri*; the interorbital space is flatter: the upper temporal foramina equal the orbits in size—a character by which the *Crocodilus Spenceri* manifestly approaches the Gavials. The nasal and superior maxillary bones are smoother; the sloping profile line of the face is straighter, and the lateral converging lines of the upper jaw are straight. These characters are well shown in the British Museum specimen.

The upper jaw slightly expands about one-third from its termination, then contracts, and again expands at the muzzle. At this anterior part the bones are more pitted than they are nearer the cranium. The alveolar margin seen in the whole skull is slightly undulating. The jugal bone is slender and nearly horizontal. The lower jaw has a large elliptical vacuity at its expanded posterior part. Its alveolar risings correspond with the sinkings of the same part in the upper jaw. In all these characters it corresponds with the *Crocodilus Schlegelii* of S. Müller.

Upon the lower surface of the skull the pterygoids in the *Crocodilus Spenceri* are terminated anteriorly by a broader and straighter transverse line; from the middle of which the palatines are continued, their posterior extremities not being expanded, as in the *Crocodili vulgaris* or *biporcatus*, but of the same breadth as the rest of the bone. The anterior and internal curved border of the transverse bones is more regular. The dental series terminates posteriorly nearer the anterior part of the transverse bone. The teeth, $\frac{22-22}{20-20} = 84$, are more uniform in size, and more regularly spaced; the intervals, however, vary from $1\frac{1}{2}$ to 2 and 3 lines; and that between the first tooth in Mr. Spencer's mutilated specimen and the second equals 7 lines. The diameter of the base of the crown of the tooth is 3 lines: there are nine of these teeth in the same extent as that which includes eleven teeth in a specimen of the *Crocodilus vulgaris*, having a skull of similar breadth. The teeth in the *Crocodilus Spenceri* are subcircular, with an anterior and posterior longitudinal ridge, with intervening fine longitudinal striæ.

The sculpturing of the cranial bones is very similar in the recent and fossil Crocodiles, but the facial bones are smoother in the *Crocodilus Spenceri*, as they likewise seem to be in the *Crocodilus Schlegelii*.

The following dimensions are taken from the skull of the *Crocodilus Spenceri* in the British Museum:—

	Ft.	In.	Ln.
Length of cranium from the lower end of the tympanic bone to the beginning of the nostril	2	0	0
Breadth of ditto between the articular end of the tympanic bones	0	10	0
From the articular end of the tympanic to the orbit	0	8	6

	Ft.	In.	Ln.
From the orbit to the nostril	0	14	6
Breadth of the cranium across the orbits	0	7	6
Ditto five inches in advance of orbit	0	3	8
Ditto across the first expansion of the jaw	0	4	0
Ditto across the nostril	0	2	8
Depth of lower jaw at the posterior vacuity	0	3	6
Length of the vacuity	0	3	0
Breadth of the base of a tooth at the first expansion	0	0	8

In the museum of Fr. Dixon, Esq., at Worthing, there is a fine fossil, referable to the *Crocodilus Spenceri*, from the Eocene clay of Bognor. It consists of a portion of the skeleton, including the lumbar, sacral, and five of the caudal vertebræ, in a continuous chain of ten inches in length, but bent in an abrupt curve.

The vertebræ, as compared with those of the *Crocodilus acutus*, have the sides of the centrum deeper or more extended vertically, and they are slightly concave; the first caudal is, as usual, bi-convex, the under surface is rather flattened. The femur presents the usual sigmoid curve, it has a well-marked medullary cavity; its length is five inches six lines. Mr. Dixon possesses, from the same locality, a posterior cervical vertebra of a Crocodile, similar in general characters to those just described, but larger, and probably belonging to an older individual. The length of the body of this vertebra is two inches and a half.

Remains of Crocodilians occur in the London clay at Hackney, and in the Eocene sand-beds at Kyson, in Suffolk; I have seen from this locality small bifurcate finely-striated conical teeth, and a small bony scutum, with regular and pretty deep pits, about the size of pins' heads.

β. *With biconcave Vertebræ.*

SUCHOSAURUS CULTRIDENS.

Gavial of the Tilgate Forest, Mantell. (?)

Teleosaurus ——, H. v. Meyer.

I next proceed to notice the fossil Crocodiles from the more recent secondary formations, and shall commence with those species with biconcave vertebræ, the remains of which are characteristic of the Wealden beds.

Amongst the evidences of Crocodilian Reptiles which are scattered through the Tilgate strata the most common ones are detached teeth, from the difference observable in the form of which, Dr. Mantell has observed, that "they appear referable to two kinds; the one belonging to that division of Crocodiles with long slender muzzles, named *Gavial*; the other to a species of *Crocodile*, properly so-called, and resembling a fossil species found at Caen *."

Dr. Mantell has obligingly communicated to me figures of well-preserved specimens of both the forms of teeth alluded to, the exactness of which I have recognized by a comparison with the specimens themselves in the British Museum.

The tooth which, from its more slender and acuminated form, approaches nearest to the character of those of the Gavial, differs from the teeth of any of the recent species of that sub-genus of Crocodilians, as well as from those of the long and slender-snouted extinct genera, called *Teleosaurus*, *Steneosaurus*, &c. I have described this form of tooth †, therefore, as indicative of a distinct species, under the name of *Crocodilus cultridens*[*]. The crown is laterally compressed, subincurved, with two opposite trenchant edges, one forming the concave, the other the convex outline of the tooth. In the Gavial, the direction of the flattening of the crown and the situation of the trenchant edges are the reverse, the compression being from before backwards, and the edges being lateral[†]. The tooth of the *Crocodilus cultridens* thus resembles in form that of the Megalosaur, and perhaps still more those of the Argenton Crocodile; but I have not observed any specimens of the Wealden teeth in which the edges of the crown were serrated, as in both the reptiles just cited. The teeth of the *Crocodilus cultridens* also present a character which does not exist in the teeth of the Megalosaur, and is not attributed by Cuvier[‡] to those of the *Crocodile d'Argenton*. The sides of the crown are traversed by a few longitudinal parallel ridges, with regular intervals of about one line in breadth, in a crown of a tooth one inch and a half in length: these ridges subside before they reach the apex of the tooth, and sooner at the convex than at the concave side of the crown.

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* Wonders of Geology, 1839, vol. i. p. 386.

† Odontography, pl. lxii. A, figs. 9 and 10.

Hitherto these teeth have not been found associated with any part of the skeleton of the present extinct Crocodilian; but from the well-marked differences between these teeth and those of all other known species, it is most probable that the extinct Crocodile formed the type of a distinct sub-genus, for which the term *Suchosaurus* might be applied.

In the Wealden strata, biconcave Crocodilian vertebræ have been discovered by Dr. Mantell differing in form from those of the Crocodilian with obtuse teeth, and readily distinguishable by their compressed and wedge-shaped body from those of all other known Crocodilians. It is highly probable that these remarkable vertebræ are parts of the same animal as the above described and equally remarkable compressed teeth.

No. $\frac{138}{2138}$, Mantellian Collection, is the body of a dorsal vertebra of this species of Crocodilian, with both articular extremities slightly and equally concave: though rather narrower at the middle than at the ends, it is more uniformly compressed than in other Crocodilian vertebræ, the sides converging to an inferior obtuse ridge, which is very slightly concave in the antero-posterior direction. The sides are not flat in the vertical direction nor slightly concave, as in many of the *Iguanodon's* vertebræ, to which the present form approximates; but are gently convex, so that a pencil laid vertically upon the side touches it only by its middle. A more decided difference between the present crocodilian vertebræ and those of the *Iguanodon* is, that the former are longer in proportion to their height and depth. The external surface at the middle of the body of the vertebra is very finely striated, so as to present a silky appearance; near the margins it is sculptured by coarse longitudinal grooves and ridges.

The base of the neurapophysis, which, when anchylosed, leaves an evident trace of the suture, is nearly equal in length with the body of the vertebra; it does not wholly include the spinal canal, but leaves the impression of the lower third of that canal upon the upper surface of the centrum.

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[*] These teeth are referred by M. H. v. Meyer to the genus *Teleosaurus*; but no portions of the skeleton of a Teleosaur have hitherto been found in the Wealden. The figures of the teeth of *Suchosaurus cultridens*, published by Dr. Mantell in the 'Illustrations of the Geology of Sussex,' pl. v. fig. 5, 6, 8, are those cited in the 'Palæologica,' p. 115. The other teeth attributed to the same species of *Teleosaurus*, by H. v. Meyer, out of Mantell, *l. c.* pl. v. figs. 1, 2, 7, 9, 10, 11, appertain to a genus equally distinct from *Suchosaurus* and from *Teleosaurus*.

[†] The tooth attributed by M. Deslongchamps to the *Poikilopleuron*, agrees in form with those of the Gavial, and differs in the characters cited in the text from those of the *Crocodilus cultridens*.

[‡] Cuvier, ix. p. 331.

In No. $\frac{123}{2123}$, Mantellian Collection, the bases of the neurapophysis remain attached to the centrum, which presents the same characters as No. $\frac{138}{2138}$. On the outside of the neurapophysis are two slightly developed broad obtuse ridges, converging towards each other from the outer side of each angle or end of the base of the neurapophysis; the ridge corresponding with the posterior of these in the *Iguanodon's* vertebra rises more vertically, and is in higher relief.

The neurapophysial suture slightly undulates in its horizontal course, and rises in the middle instead of descending upon the centrum, as in the Plesiosaurs.

The present vertebra is alluded to at p. 70, and figured at pl. ix. fig. 11, of Dr. Mantell's 'Illustrations of the Geology of Sussex,' as a lumbar vertebra of the *Megalosaurus*. But in the 'Geology of the South-east of England,' the accomplished author, speaking of this vertebra, observes, "It cannot, I now think, be separated from those figured in the same plate, as belonging to a crocodile."—p. 297. Fig. 8, pl. ix, (Tilgate Fossils) is, however, a caudal vertebra of the *Cetiosaurus*. As I have examined with care the original vertebra of the *Megalosaurus*, figured after Buckland, and referred to by Dr. Mantell at pl. xix. fig. 16 of the same work, I can attach the greatest confidence to the following differences:—the body of the Megalosaurian vertebra has a pretty deep longitudinal depression below the neurapophysial suture, wanting in the Tilgate vertebra here described. This, however, is not the only distinction; below the depression the body of the Megalosaurian vertebra swells out, and is as convex below as it is laterally in the transverse direction, so that the outline of a transverse section would describe five-sixths of a circle: a similar section of No. 123 would be triangular with the apex rounded off. The Megalosaurian vertebra is more contracted at the middle, and swells out near the articular ends, surrounding those articulations with a thick convex border: in No. 123 the lateral meet the marginal surfaces at a somewhat acute angle; but the silky striated surface of the Crocodilian vertebra, and the smooth and polished surface of the Megalosaurian one, would effectually serve to distinguish even fragments from the middle of the body of each.

The following are dimensions of the two vertebræ of the large Wealden Crocodilian above described:—

	No. 123.		No. 138.	
	In.	Lines.	In.	Lines.
Antero-posterior diameter of the body . . .	3	4	3	10
Vertical diameter of its articular end	2	5	3	2
Transverse diameter of its articular end . . .	2	10	2	9
Transverse diameter of the middle of the body	2	0	2	0

GONIOPHOLIS CRASSIDENS, O.

Swanage Crocodile, Mantell.

Teleosaurus ——, H. v. Meyer.

The second form of tooth having the generic characters of those of the Crocodile, which has been discovered in the Wealden and approximate strata, is as remarkable for its thick, rounded and obtuse crown as the teeth of the preceding species are for their slender, compressed, acute and trenchant character. It consequently approaches more nearly to the teeth which characterize the broad and comparatively short-snouted Crocodiles; but it differs from these in one of the same characters by which the tooth of the *Suchosaurus cultridens* differs from those of the Gavials, viz. in the longitudinal ridges which traverse the exterior of the crown. These are, however, more numerous, more close-set, and more neatly defined than in the *Suchosaurus cultridens*. Two of the ridges, larger and sharper than the rest, traverse opposite sides of the tooth, from the base to the apex of the crown; they are placed, as in the Crocodile and Gavial, at the sides of the crown, midway between the convex and concave lines of the curvature of the tooth. These ridges are confined to the enamel; the cement-covered cylindrical base of the tooth is smooth. The size of the teeth varies from a length of crown of two inches, with a basal diameter of one inch and a half to teeth of one-third of these dimensions.

Hitherto no teeth of the *Goniopholis* appear to have been discovered in the oolite near Caen; the only specimens resembling them being those which Cuvier has stated to indicate a second species of Crocodilian, from the Jura limestone at Soleure*. No other remains referable to this species are noticed by Cuvier; but the discovery of a portion of the skeleton, having in the lower jaw two teeth identical with the obtuse teeth of the Wealden, has thrown much light upon the characters of this interesting species.

The circumstances connected with this discovery are thus narrated by Dr. Mantell:—"In the summer of 1837, the workmen employed in a quarry in the immediate vicinity of Swanage, had occasion to split asunder a large slab of the Purbeck limestone, when, to their great astonishment, they perceived many bones and teeth on the surfaces they had just exposed. As this was no ordinary occurrence,—for although scales of fishes, shells, &c. were frequently observed in the stone, bones had never before been noticed,—both slabs were carefully preserved by the proprietor of the quarry." They were obtained by Robert Trotter, Esq., F.G.S., and presented by him to Dr. Mantell, by whom the bones were relieved from the matrix, so far as their brittle state would permit. The specimen has subsequently been purchased by parliament, and, with the rest of Dr. Mantell's collection, is now deposited in the British Museum.

Figures of this interesting group of bones have been published by Dr. Mantell in his 'Wonders of Geology,' vol. i. pl. i.; but, excepting the remark above quoted, with regard to the nearer approach which the fossil makes in the form of its teeth to the sub-genus *Crocodilus*, as compared with the more slender Wealden tooth, no other observation has been published which tends to establish more precisely and closely the true affinities and nature of the Swanage Crocodilian.

The first character which attracts attention is that which the numerous, large, bony, dermal plates or scutes afford. These are scattered irregularly over the slab, and in their number and relative size bring the species much nearer to the extinct Teleosaurs than to any of the existing Crocodiles; they differ, however, from both the dorsal and ventral scutes of the Teleosaur in their more regular quadrilateral figure; they are longer in proportion to their breadth than most of the Teleosaurian scutes, and are distinguished from those of all other Crocodilians, recent and fossil, that I have yet seen, by the presence of a conical, obtuse process, continued from one of the angles vertically to the long axis of the scute, analogous to the peg or tooth of a tile, and fitting into a depression on the under surface of the opposite angle of the adjoining scute; thus serving to bind together the plates of the imbricated bony armour, and repeating a structure which is highly characteristic of the large bony and enamelled scales of the extinct ganoid genera of fishes, *Dapedius* and *Tetragonolepis*. Many of the scutes are 6 inches in length and 2½ inches in breadth.

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* "On trouve parmi ces os du Jura une petite dent pointue et un peu tranchante, fort semblable à celle du Crocodile de Caen," *l. c.* ix. p. 283, pl. ccxxxiv. fig. 8, *i. e.* the *Teleosaurus Cadomensis*, the teeth of which are "longues, grêles, arquées, et très-pointues, mais non pas tranchantes." *Ibid.* p. 271. Cuvier then proceeds to say, "Mais il y en a aussi de beaucoup plus grosses et plus obtuses, telles que celle de la fig. 7, qui pourraient annoncer une autre espèce." *Ibid.* p. 283. It is with this other species that the blunt-toothed Crocodilian of the Wealden and Purbeck limestone bears most resemblance.

The exterior surface of the scute is impressed, as in the Teleosaur, by numerous deep, round, or angular pits, from two to four lines in diameter, and with intervals of about two lines, formed by convex reticularly disposed ridges of the bone; but a larger proportion of the anterior part of the scute is overlapped by the contiguous scute than in the Teleosaur, and this part is smooth, and thinner than the rest of the scute. The whole of the inner surface of the scute is smooth; but on a close inspection it is seen to be everywhere impressed by fine straight lines, decussating each other at nearly right angles, and indicating the structure of the corium in which the scutes were imbedded. From the size and strength of these dermal bones, their degree of imbrication, and the structure for interlocking, we may conclude that the Swanage Crocodilian was better mailed than even the extinct Teleosaur, which Cuvier regarded as "l'espèce la mieux cuirassée de tout le genre."

If the detached vertebræ from the Wealden, communicated by Dr. Mantell to Cuvier, belonged to the obtuse-toothed species and not to the *Suchosaurus cultridens*, it would then have been known that the Swanage Crocodile deviated, like the Teleosaur and most extinct Crocodilian species of the secondary strata, from the Crocodiles, Alligators, and Gavials of the present day, in having both articular extremities of the body of the vertebra slightly concave.

Cuvier* has associated the obtuse teeth with this form of vertebra without hesitation; but it must be admitted that there was room for some doubt, two distinct species, at least, having been indicated by the fossil teeth.

In the slabs between which the remains of the Swanage Crocodile are divided, the vertebræ were unfortunately all at right angles to their plane, and are fractured across the middle, one extremity being buried in one of the halves of the slab, and the other in the opposite half. By permission of the Trustees of the British Museum, and the kind aid of the distinguished Mineralogist at the head of the Geological Department, this doubt has been solved since the reading of the present Report at Plymouth. The limestone has been carefully removed from the two extremities of the same vertebra, and both are equally but slightly concave.

	In.	Lines.
The length of the body of the vertebra examined was . .	1	10
Vertical diameter of the articular extremity	1	9
Transverse diameter of the articular extremity	1	8
Ditto of middle of the body	0	11
Ditto of entire vertebra, including the transverse processes	10	0
Height of entire vertebra, including spinous process . .	4	4
From the lower part of the centrum to the base of the transverse process	2	6

There is a small irregular medullary cavity in the centre of the body of the vertebra: this cavity is much more capacious in the *Poikilopleuron*: the exterior compact crust of the body of the vertebra is about two lines in thickness. The suture which joins the neural arch to the centrum is conspicuous; it forms an ascending angle or curve at its middle part. The body of the vertebra expands in a greater degree to form the subconcave articular surfaces than in other biconcave vertebræ of the same length; and both in this character, in its smooth surface, and circular transverse contour at the lower part, the *Goniopholis* resembles the *Streptospondylus* more than it does the *Teleosaurus*.

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* "Les vertèbres sont un peu concaves aux deux extremités, ce qui les rapproche du Crocodile de Caen et du deuxième de ceux de Honfleur; cependant je les trouve plus voisines du premier pour l'ensemble. Les dents sont pour la plûpart plus obtuses même que dans nos Crocodiles vulgaires, et ressemblent en ce point à la seconde du Jura que j'ai décrite ci-dessus."—*L. c.*, p. 323.

The medullary canal, at the middle of these vertebræ, presents in transverse section the form of an inverted triangle, the apex sinking into the body of the vertebra. The transverse processes of the lumbar and anterior caudal vertebræ are long, straight, and comparatively slender; those of the sacral vertebræ are relatively thicker, and the spaces inclosed by their expanded extremities are smaller than in either the Teleosaurs or true Crocodiles. The antero-posterior extent of the two sacral vertebræ is three inches two lines.

The ilium is broader than in the existing Crocodilians; the bifurcation of the proximal end of the ischium is more marked, and the iliac branch is more regularly rounded; the pubic branch is longer, more slender, and its articular end is more regularly convex; the distal or lower part of the ischium expands into a relatively broader plate. This character is still more conspicuous in the pubis, which equals the ischium in breadth, and begins to expand much nearer the proximal extremity than in the existing Crocodiles. In these modifications of the pelvis, as well as in the biconcave structure of the vertebra, the Crocodilian of the Purbeck limestone approaches nearer to the characters of the Enaliosaurs; and we may infer that its habits were more decidedly marine than are those of existing Crocodilians. The caudal vertebræ were provided with long, narrow, unanchylosed chevron bones.

The portion of the lower jaw preserved belongs to that part of the left ramus included between the articular extremity, which is broken off, and the commencement of the dental series; it measures one foot six inches in length, and five inches in greatest depth. In these proportions, and the curve of the lower margin, it deviates from the ancient Teleosaurs and Steneosaurs, and resembles the modern Crocodiles; and although not quite equalling these in the robust proportions of the jaws, yet it much exceeds in this respect the Crocodilians with more slender teeth. What the real length and form of the jaws may have been, and how nearly they may have approached the Gavial type, there is not at present means to determine. Sufficient, however, has been pointed out from the remains which are at present discovered, to show that the Swanage Crocodilian differs from the existing subgenera of Crocodilians in a greater degree than these do from one another; that in the form of its vertebræ and the structure of the dermal armour, it is much more nearly allied to the *Teleosauri* and other Crocodilian genera of the biconcave vertebral system; and that, in this ancient and extinct group of Crocodilians, it typifies the Alligator family of the Crocodilians of the ball-and-socket vertebral system.

I propose to name the subgenus indicated by the known remains of the Swanage Crocodile, *Goniopholis*, in reference to the rectangular form, size, number, and firm junction of the osseous scutes (φολίδες), with the specific name of "*crassidens*."

In a collection of fossil Saurian remains from the Hastings beds in the possession of Gilpin Gorst, Esq., F.G.S., is the base of the tooth of the *Goniopholis crassidens*, eight lines in diameter.

Remains of Crocodilians are stated by Dr. Mantell to have been found, though very rarely, in the lower chalk, and in the grey chalk at Dover[*].

TELEOSAURUS.

The family of extinct Crocodilians, which next remains to be noticed, is characterized by a combination of a biconcave structure of the vertebræ, with long, narrow jaws, armed with slender, conical, sharp-pointed and equal teeth, adapted, like those of the existing Gavials, for the seizure and destruction of fishes. The species are separated into two genera, according to the difference of position in the external nostril, which, in the one called *Teleosaurus*, is terminal, or at the extremity of the upper jaw; in the other, called *Steneosaurus*, is a little behind and above the termination of the upper jaw. The species of both genera are confined to the oolitic division of the secondary rocks, and, since there were scarcely any Mammalia during that period, whilst the waters were abundantly stored with fishes, it might, *à priori*, have been expected, Dr. Buckland justly observes, "that if any Crocodilian forms had then existed, they would most nearly have resembled the modern Gavial*." The modification in the structure of the vertebral column, and their complete mail of imbricated bony scutes, also indicate that the habits of the ancient *Teleosauri* and *Steneosauri* were more strictly marine than are those of the modern Gavials, and that their powers of swimming, of pursuing and overtaking their aquatic prey, were greater.

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[*] Illustrations of the Geology of Sussex, 4to, 1827, p. 64.

The extinct reptile from which the characters of the genus *Teleosaurus* are derived, is one of the earliest of the evidences of ancient Reptilia which is recorded in a scientific publication. A brief description, and figures of an incomplete skeleton found in the lias (alum schale) of the Yorkshire coast, about half a mile from Whitby, were published by Messrs. Wooller and Chapman, in two separate communications, in the 50th volume of the Philosophical Transactions, 1758, (Pt. 2, pl. xxii. and xxx.). Their figures exhibit a contorted and incomplete vertebral column, about nine feet long, and a cranium slightly displaced, two feet nine inches in length. About ten vertebræ of the lumbar and sacral region of the trunk, and twelve vertebræ of the tail remain in place; the cervical, dorsal, and middle coccygeal vertebræ were indicated only by their impressions; and these are fewer in number than the vertebræ in the existing Crocodiles. The skull is reversed, presenting its basal surface to view: the single occipital condyle, the zygomatic arches, terminated behind by the strong tympanic bones, and the large convex articular surface in each of these, for the lower jaw, placed in the same transverse line as the occipital condyle, are all recognizable. The skull appears to contract gradually to a pointed muzzle, but in reality to the base of a long and slender maxillary beak. In the remaining basal or posterior portions of the jaws, the sockets of the teeth are seen separated by intervals of about nine lines; in some of these there are pointed conical teeth, which cross alternately those of the opposite jaw. The teeth are covered with polished enamel†.

Each of the vertebræ is three inches in length. Near the pelvic region, the shaft of the femur, including the head, was exposed, measuring between three and four inches in length. A few fragments of ribs were found near the dorsal vertebræ. The authors of the papers just analysed perceived sufficient resemblance between their fossil and the skeleton of the Crocodile to refer it to that family of reptiles‡; but their figures and descriptions gave rise to various opinions respecting the affinities of the Whitby fossil in the writings of subsequent naturalists and anatomists. Camper, for example, pronounced it to be a whale, perhaps meaning a dolphin, for, as Cuvier remarks, the presence of teeth in both jaws at once proves the fossil not to belong to the Balænæ, which have no teeth, nor to the Physeters, which have (conspicuous) teeth only in the lower jaw. Faujas adopted Camper's opinion, referring the fossil to the genus *Physeter*, and adding some reasons which are contradicted by the descriptions given by both Chapman and Wooller. Cuvier, in the first edition of his 'Ossemens Fossiles,' after refuting the opinion of Faujas, says, "La vérité, ainsi que nous le verrons, est que c'étoit réellement un crocodile." The subsequent analysis, to which Cuvier here refers, led him in 1812 to the conclusion that it belonged to the genus of Crocodiles, and was most probably identical in species with the Crocodile of Honfleur.

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* Bridgewater Treatise, vol. i. p. 250.

† Cuvier truly states, "Elles n'ont pas été décrites particulièrement, et il est impossible de juger de leurs caractères par la gravure."—Oss. Foss. 1836, ix. 225.

‡ Captain Chapman says, "It seems to have been an alligator;" (*l. c.*, p. 691.) and Mr. Wooller thinks that "it resembles in every respect the Gangetic Gavial." It will be shown, however, that the fossil really differs more from the Gavial than the Gavial does from any other existing Crocodilian.

In 1836, however, when so many new and singular genera, allied to the Crocodilian family, had been added to the catalogues of Palæontology, chiefly by the labours and discoveries of English anatomists and geologists, Cuvier expresses his opinion on the fossil described by Wooller and Chapman with more caution. He says, "Il reste maintenant à savoir si c'est un crocodile, ou l'un de ces nouveaux genres découverts dans les mêmes bancs. Les os des extremités y sont trop incomplets, et la tête n'y est pas représenté avec assez de détails pour décider la question ; mais les vertèbres me paraissent plus longues, rélativement à leur diamètre, que dans les nouveaux genres, et plus semblables par ce caractère à celles des Crocodiles. Ceux qui retrouveront l'original, s'il existe encore, pourront seuls nous apprendre si les autres caractères répondent à celui-la."

I have made inquiry at the British Museum, to which the collections formerly belonging to the Royal Society were transferred, but no specimen corresponding with the account and figures given by the Whitby naturalists exists in that collection.

A second specimen of a long and slender-nosed Crocodilian, was obtained from the lias near Whitby, between Staiths and Runswick, in the year 1791*; and a more perfect skeleton was discovered in the alum shale of the lias formation at Saltwick, near Whitby, in 1824. Both these specimens so closely resemble the older fossil in all the points in which a comparison can be established, as to dissipate the remaining doubts as to the nature and affinities of the specimen from the same locality, described in the Philosophical Transactions for 1758. The skeleton, discovered in 1824, is figured in Young and Bird's 'Geological Survey of the Yorkshire Coast', 2nd edit. 1828, pl. xvi. fig. 1. p. 287, and in Dr. Buckland's 'Bridgewater Treatise,' vol. ii. pl. xxv. It is now preserved in the museum at Whitby, where I have closely examined it. In this specimen are preserved the cranium, wanting the snout, the whole vertebral column, the ribs, and the principal parts of the four extremities, together with the dorsal, and part of the ventral series of dermal bones. The entire length of the skeleton, following the curvature of the spine, is fifteen feet six inches, to which may be added two feet six inches for the lost snout. The cranium posteriorly is broad, depressed, and square-shaped : it begins to contract anterior to the orbits, and gradually assumes the form of the narrow depressed snout; the converging sides of the maxillæ are concave outwardly. The zygomatic spaces are quadrilateral, longer in the axis of the skull than transversely; the orbits are subcircular; they look upwards and slightly outwards ; their margins are not raised, and their interspace is slightly concave. The parietal bone is relatively longer than in the Gavial, and sends up a longitudinal median crest, from the posterior part of which a strong process extends on each side outwards, and curves slightly backwards parallel with the ex-occipitals, to join the mastoid and tympanic bones, the latter of which expands as it descends to form the joint for the lower jaw.

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* See History of Whitby, vol. ii. pp. 779, 780.

	Feet.	In.	Lines.
Breadth of posterior part of skull	1	0	0
Length of parietal crest	0	6	0
Breadth of the interorbital space	0	3	2
Antero-posterior diameter of the middle of tympanic pedicle	0	2	5
Vertical diameter of orbit	0	2	0
Antero-posterior of orbit	0	3	0
From lower margin of orbit to alveolar border	0	1	3

From these dimensions it may be calculated that the entire length of the skull must have exceeded 4 feet 6 inches.

The skull of one of the Caen *Teleosauri* measures 3 feet 4 inches, whence Cuvier calculates the entire length of the animal at near 15 feet. The Whitby Teleosaur agrees with the Caen species, and differs from the Gavial in the following particulars: the anterior frontal is less extended upon the cheek; the lachrymal is much more extended, and is larger at its base; the jugal bone is more slender. The posterior frontal, which separates the temporal from the orbital cavities, is much longer and narrower. The parietal and occipital crests each form a thin trenchant plate, and are not flattened above. The mastoidean angle is not uninterruptedly united with the back part of the articular process of the tympanic, it is separated from it by a large depression, which is overarched by a trenchant crest belonging to the ex-occipital. The mastoidean bone has a concavity at its descending part, of which there is no trace in the Gavial. The indentation between the articular process of the tympanic, and the tuberosity of the basi-occipital is much smaller than in the Gavial, and the basilar tuberosity projects downwards in a less degree. The pterygoid ala is not expanded externally, as in all Crocodiles, but is contracted by a large fissure, at the part where it goes to unite itself to the bone; the orbital margin of the malar is not raised, and does not leave behind it a deep fissure as in the Gavial. The malar does not rise to join the posterior frontal bone; but, on the contrary, the frontal descends to join the malar at the external margin of the orbit. The vacuity between the orbit and the anterior part of the tympanum is much elongated in the fossil, and occupies four-fifths of the temporal fossa; the anterior part of this fossa is narrow and acute. The columella or ossicle of the ear is cylindrical, and much larger in proportion than in any known Crocodile or other reptile.

Cuvier calculates the number of teeth in the *Teleosaurus Cadomensis* to be 180, viz. $\frac{45-45}{45-45}$.

The *Teleosaurus Chapmanni* has at least 140 teeth.

The Gavial has 112, or $\frac{28-28}{28-28}$.

The teeth of the Whitby Teleosaur are as slender and sharp-pointed, but not so compressed, as in the Gavial; they correspond with those of the Caen Teleosaur, and equally illustrate the dental characters usually attributed to the present extinct genus*.

The Whitby Teleosaur differs from the Caen Teleosaur, as does the

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* M. H. v. Meyer refers to the genus *Teleosaurus* (Palæologica, p. 115) the thick obtuse teeth of the Wealden or Sussex Crocodile figured by Dr. Mantell in his 'Illustrations of the Geology of Sussex,' at pl. v. figs. 1, 2, 7, 9, 10, and 12. These teeth, however, belong to *Goniopholis*, as does also the scute figured in pl. vi. fig. 8; and they are accompanied with deviations from the characters of *Teleosaurus* in the skeleton as striking as those which are manifested in their own robust and obtuse figure.

Monheim Teleosaur*, in having the upper temporal fossæ longer in proportion to their breadth; but it differs from the Teleosaurs of both Caen and Monheim in the more equal size of the teeth, and from the Monheim species in the greater number of teeth, the *Teleosaurus priscus* having at most $\frac{27-27}{26-26} = 106$. The median frontal in the Whitby Teleosaur is slightly concave: in the Caen species it is flat. The basi-occipital is perforated by the common terminal canal of the Eustachian tube close to the junction with the sphenoid, and, on each side of the hole, it expands into a rough tuberosity. The body of the sphenoid is compressed, characterized by two processes or narrow ridges, continued one from each side of the middle of the sphenoid obliquely backwards. The pterygoid bones are relatively smaller than in the Gavial. The palatine bones are more extended posteriorly, and articulate with the transverse bones. The posterior apertures of the nasal canals are placed more forwards upon the base of the skull than in existing Crocodiles.

Vertebral Column.—The number of vertebræ in the true Crocodiles of the present period rarely exceeds sixty, which is the number originally assigned by Ælian† to the spinal column of the Crocodile of the Nile. Cuvier generally found 7 cervical, 12 dorsal, 5 lumbar, 2 sacral, and 34 caudal vertebræ.

In the *Crocodilus acutus* a thirteenth pair of ribs is occasionally developed, and, according to Plumier, it has two additional caudal vertebræ.

The Alligator (*Alligator Lucius*) has sixty-eight vertebræ, the additional ones being in the caudal region.

The Gavial has sixty-seven vertebræ, disposed as follows:—7 cervical, 13 dorsal, 4 lumbar, 2 sacral, and 41 caudal vertebræ.

The very perfect specimen in the Whitby Museum displays the number of the vertebræ through the whole spinal column, and establishes another difference between the Teleosaur and the Gavial, the former having a number of vertebræ intermediate between the Crocodiles and Gavials, viz. 64, with a special peculiarity in the excess of costal vertebræ, as the following formula indicates, viz. 7 cervical, 16 dorsal, 3 lumbar, 2 sacral, 36 caudal.

In all sub-genera of existing Crocodiles, as in the extinct tertiary species, the hind surface of the vertebra is convex, the fore surface concave, except in the atlas and the two sacral vertebræ.

Cuvier, who had the opportunity of seeing only the annular part (neurapophyses) of the cervical vertebræ of the Caen Teleosaur, regrets his inability to state whether either of the articular extremities of the centrum were convex, or which of them‡. The Whitby Teleosaur decides this question, and shows that both articular extremities of the vertebræ are slightly concave in the cervical as in the rest of the vertebral series.

The atlas in the Teleosaur corresponds essentially with that of the Crocodiles, as is shown by the three main component parts of this bone, from a Whitby Teleosaur in Lord Enniskillen's collection. The body or centrum is a transverse quadrilateral piece, smooth and convex below, narrowing like an inverted wedge above, with six articular facets, viz. a concavity in front for the occipital condyle, a flat rougher surface on each side of the upper part for the attachment of the neurapophyses; a posterior facet for the anterior part of the detached odontoid element of the axis; and the small surface on each lateral, posterior and inferior angle for the atlantal ribs. The neurapophyses are pyramidal processes, with their apices curved towards each other; they are relatively smaller in proportion to the centrum than in the Crocodiles.

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* *Crocodilus priscus*, Soemmerring.

† De Naturâ Animalium, lib. x. sect. xxi, Jacob's Ed., 8vo, vol. i. p. 228.

‡ Ossem. Fossiles, 4to, 1824, tom. v. pt. ii. p. 137.

The general anterior concavity for the reception of the occipital tubercle is formed at its circumference by the centrum and neurapophyses of the atlas, and at its middle by the anterior detached odontoid epiphysis of the axis, which is here evidently the analogue of the so-called atlas in the *Ichthyosaurus*, the true body of the atlas in the Teleosaur representing the first inverted wedge-shaped bone in the Ichthyosaur. The spine of the atlas is a large strong oblong piece, articulated with the neurapophyses of the atlas, and partly overlapping those of the axis.

The cervical vertebræ have strong transverse processes developed one from each side of the centrum, and one from the base of each neurapophysis. The posterior articular processes look obliquely downwards and outwards, the anterior ones obliquely upwards and inwards. The spinous process is compressed, its base coequal with the whole antero-posterior extent of the neurapophysis; its height equal to the distance from its base to the upper transverse process; it inclines slightly backwards, and is slightly rounded off at the summit. The cervical rib is bifurcate at its vertebral end, the tubercle being as long as the head and neck; its distal end is expanded into the hatchet shape, the posterior angle being most produced, and overlapping the costal process of the next vertebra behind. The same mechanism for fixing and strengthening the neck thus existed for the advantage of the ancient marine Crocodiles, as we find in those of the existing epoch.

In the dorsal region the ribs exchange the hatchet for the ordinary lengthened form, and soon begin to lose the head and neck, as in existing Crocodiles; after the fifth they no longer articulate with the central element, but only to the transverse process of the neurapophysis, which increases in antero-posterior extent and thickness, and presents an oblique notch at its anterior angle, for the reception of the tubercle, now the only head of the rib. The number of the dorsal ribs exceeds that of any existing Crocodilian, being, as above indicated, 16 pairs. The spinous process is proportionally strong; in the Whitby specimen it measures in most of the dorsal vertebræ 2 inches in antero-posterior extent, and seven lines in transverse diameter or thickness: the height of these spines seems not to have much exceeded that of the cervical spines, but they are more truncated at the summit.

A posterior dorsal or lumbar vertebra of a Teleosaur from the Whitby lias, in the collection of Mr. Ripley, corresponds with the vertebral characters of *Teleosaurus* in the slight concavity and circular contour of the terminal articular surfaces of the body, and in the great antero-posterior extent of the spinous processes; but that of the transverse process does not exceed one-half the length of the body of the vertebra, which is 2 inches 6 lines. The transverse process is supported by two short obtuse slightly-developed ridges, which rise from the upper part of the side of the body, as far apart as to include one-third of the length of the body between them, and converge to the under part of the transverse process; a similar ridge extends from the upper part of the posterior end of the transverse process obliquely backwards to the base of the posterior articular process. The neural arch is anchylosed to the centrum in this vertebra. The supporting buttresses of the transverse processes are not described by Cuvier in the dorsal vertebræ of the Caen Teleosaur; nor have I met with any dorsal or lumbar vertebræ of the Whitby species, except the present, that was sufficiently perfect to exhibit this character; it may, however, be constant and characteristic of the genus. It faintly indicates one of the most striking characters of the vertebræ of the *Streptospondylus*. The anterior and posterior margins of the spinous process are slightly excavated, and thus retain a character which is transitory in the Crocodile, and peculiar to an early period of its existence.

The transverse processes of the two sacral vertebræ are thick, strong and expanded at their extremities.

The bodies of all the vertebræ are compressed laterally, and concave antero-posteriorly at the sides; but this character is more strongly marked in the anterior caudal vertebræ, which are flattened along the inferior surface; these vertebræ in the Whitby specimen were 2 inches 8 lines in length. The transverse processes are longer, but narrower antero-posteriorly than in the lumbar or dorsal vertebræ. The hæmapophyses are united at their peripheral end, forming chevron bones, but are detached at their central ends, which are articulated, as in recent Crocodiles, with the interspaces of the vertebral centres. The caudal vertebræ progressively diminish in every diameter, save length, from the middle to near the end of the tail; the terminal vertebræ are shorter than the rest.

The sternum and sternal ribs closely agree with the ordinary Crocodilian type. I have not yet seen a specimen of the abdominal sternal ribs.

Pectoral extremities.—The scapula and coracoid resemble, in general form, those of the Crocodile, but are relatively smaller, in correspondence with the smaller size of the anterior extremities. The *scapula*, for example, is only one-third the length of the femur; it is straighter than that of the Crocodile; both margins are nearly equally concave, instead of the anterior one being convex: the humeral end is less expanded, and is more obliquely truncated. The *coracoid* is longer than the scapula, instead of being, as in the Crocodiles, shorter: this probably depends upon the breadth of the fore part of the body, which regulates the extent of the coracoid, while the proportions of the scapula more exclusively depend upon the development of the pectoral extremity. The coracoid of the Teleosaur differs also from that of the Crocodile in the greater expansion of its humeral end, the more transverse position of its sternal convex extremity, and a nearer approach to parallelism in the direction of the two lateral margins.

In the Whitby Teleosaur, discovered in 1824, the humerus of the right anterior extremity, and the humerus and bones of the fore-arm of the left are preserved nearly in their proper relative positions. The humerus is shorter in proportion than in the Crocodiles, its length scarcely exceeds the antero-posterior diameter of two of the cervical vertebræ. The antibrachial bones are still more curtailed in their proportions; the longest bone, or ulna, being not quite half the length of the humerus.

No portions of the carpal or other bones of the paddle are preserved, but the presence of the antibrachial bones, distinct from each other, and of the ordinary form and breadth at the distal end, forbid our supposing them to have been naturally deficient or of abortive proportions in the *Teleosaurus*. The humerus, radius and ulna must have existed for a purpose, and that purpose, we may conclude, from the modifications for an aquatic life in the rest of the skeleton, to have been the support and movement of a palmated manus; an organ which would be of great use in turning and regulating the course of the swimmer, and in bringing the long and slender snout, with the terminal nostrils, to the surface. The fore-paddles were doubtless much smaller than in ordinary Crocodiles, and this difference of proportion related both to the less frequent resorting of the Teleosaur to dry land, and to the light and slender character of its jaws and teeth, and the consequent diminution of the weight of its head.

Pelvic extremity.—The pelvis of the Teleosaur was attached, as in the Crocodile, to the thickened and expanded transverse processes of two sacral vertebræ. These processes are stronger in the vertical direction, and intercept a relatively smaller and more regularly elliptical space than in the existing Crocodiles; the anterior one appears not to have been so much expanded in the antero-posterior direction. The iliac bone seems to have been shorter in the antero-posterior diameter, but longer, as measured transversely to the axis of the trunk, and thus to have made a slight approach to its characteristic form in the Enaliosaurs.

Both the ischium and pubis are relatively more expanded than in the Gavial. The pelvic extremities are preserved in the Whitby specimen in nearly their true relative positions; but the right is thrown directly over the left. The femur presents the usual Crocodilian form, but is relatively more slender than in the existing Crocodilians; it is slightly twisted, and bent in two directions. Its proximal end is expanded, compressed with a regular convex curve, describing a semicircle; the trochanter is represented by a ridge which gradually subsides, and is lost upon the surface of the shaft. This is nearly cylindrical at the upper part, but is produced at the anterior or convex side along the distal half in the form of an obtuse ridge. The condyles are very feebly indicated. In the Whitby specimen of 1824,

	Feet.	In.	Lines.
The length of the femur is	1	3	3
The breadth of proximal end of ditto . .	0	2	10
The diameter of middle of shaft	0	1	4

Both the tibia and fibula are subcompressed towards their distal end: the length of each bone is 8 inches. The shaft of the fibula is nearly as thick as that of the tibia. The bones of the leg of the *Teleosaurus* resemble those of the Aëlodon in their relative shortness as compared with the femur. In these, and probably in other ancient Crocodiles with biconcave vertebræ and marine habits, the tibia is little more than half the length of the femur; while in recent Gavials it is two-thirds that length. There are five tarsal bones, two in the proximal and three in the distal row, as in the Gavial; but they are of more equal size; the two proximal bones being by no means so disproportionately large. All the long bones have distinct medullary cavities, and these are even present in the metatarsals. In the Whitby specimen,

The length of the middle metatarsal is	6 inches.
The breadth of its proximal end	10 lines.
The breadth of its distal end	6 lines.

The ungual phalanges are depressed, smooth and convex above, rounded at the end.

Dermal armour.—The bony dermal scutes of the Teleosaur were regularly disposed like those of existing Crocodiles, in both longitudinal and transverse series; the posterior margin of one scute covered the base of the succeeding scute*, and they slightly overlapped each other laterally.

Cuvier states that one of the fossils of the *Teleosaurus Cadomensis* presents all those of one side in their natural situation, exhibiting, in the part of the body included between the first dorsal and the beginning of the tail, fifteen or sixteen transverse rows, containing five scutes on each side; so that there were at least ten longitudinal rows of these dermal bones.

The scutes are arranged in the same manner and number, at least as regards the transverse rows, in the Whitby Teleosaur; these rows being indicated by the large dorsal scutes still occupying their natural position in an uninterrupted line along the back; they are twenty in number, and sixteen cover the vertebræ included between the last cervical and first caudal.

The scutes of the *Teleosaurus Chapmanni* differ as much from those of the existing Gavials and Crocodiles, as do those of the *Teleosaurus Cadomensis*, being thicker, rectangular, and having the outer surface impressed with circular pits or indentations from three to four lines in diameter, which are not confluent, but separated.

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* Cuv., *l. c.* p. 279.

The median dorsal scutes of the Whitby specimen are nearly square, having the longer diameter, about three inches and a half across, placed transverse to the axis of the body, and with the outer margin slightly rounded. Each of these scutes is traversed, as in the *Teleosaurus priscus*, by a longitudinal ridge, which is less developed than in the Gavials. The median dorsal scutes of the *Teleosauri Cadomensis* and *priscus* appear to differ from those of the *Teleosaurus Chapmanni* in being more oblong transversely, and with the posterior and lateral margins rounded off. Cuvier does not allude to the carinated character of these plates in the Caen species.

The lateral and ventral scutes of the *Teleosaurus Chapmanni* are more perfect squares than those next the spine, but differ less in form and size from them, than in the Caen Teleosaur. They are marked externally by the same impressed pattern, but are not carinated. The median abdominal scutes are not opposite but alternate; their median margins are rounded off, or slightly angular; and, while the anterior part of that margin is overlapped by the posterior half of the opposite scute, in advance, the posterior half overlaps the succeeding scutum of the opposite side. The verticillate cuirass of these ancient Crocodiles is thus securely braced round the trunk by this interlocking of the inferior extremities of each ring of scutes, whilst the imbricated arrangement would allow of a certain sliding motion of the rings upon each other sufficient for the expansion of the chest in breathing. The scutes in the fine specimen in the Whitby Museum measure about five lines in thickness, but are thinned off at the edge.

Having now detailed the anatomical particulars which a study of the magnificent and unique skeleton of the *Teleosaurus*, in the museum at Whitby, has enabled me to add to the previous descriptions, by Cuvier and other anatomists, of the osteological structure of this extinct Crocodilian genus, I next proceed to notice the principal examples of the same genus which are preserved in other collections of British Fossil Reptiles.

The first of these is a fine skull of the same species of *Teleosaurus*, and from the same lias beds near Whitby, in the museum of Mr. Ripley of that town:—

	Feet.	Inches.
The length of the entire skull is	2	9
From the angle to the beginning of the long symphysis of the lower jaw	1	3
Breadth of the lower jaw at the posterior commencement of symphysis	0	2½
Breadth of the extremity of the lower jaw	0	1

The extremity of the upper jaw well exhibits in this specimen the characteristic generic modification of its infundibuliform expansion, supporting the terminal nostrils, and resembling the extremity of the elephant's proboscis, wanting the digital process.

This cranium also clearly exhibits the specific characters by which the *Teleosaurus Chapmanni* of the Yorkshire lias differs from the *Teleosaurus Cadomensis* of the Caen oolite, viz. the greater antero-posterior extent of the upper temporal openings as compared with their transverse diameter in the *Teleosaurus Chapmanni*; the similar but slighter difference in the form of the orbits, the greater breadth of the interorbital space, which slightly exceeds the transverse diameter of the orbit instead of falling short of that diameter, as in the *Teleosaurus Cadomensis*.

A cranium of the *Teleosaurus Chapmanni*, in the museum of the Philosophical Institution at York, and another in the museum at Scarborough, offer the same specific characters as the Whitby specimens. In the Scarborough cranium the diameter of the orbit is 2 inches 3 lines, while that of the interorbital space is 2 inches 6 lines.

In the museum of the Natural History Society at Lancaster there is a chain of five dorsal vertebræ of the *Teleosaurus Chapmanni*, from the Whitby lias, measuring 1 foot in length; each vertebra is 2 inches 4 lines in length. A section of these vertebræ showed a small cavity in the centre of the cancellous structure of the body*.

Teleosaurus Cadomensis.—Specimens of fragments of the jaw, teeth and vertebræ of this species have been discovered in the Bath oolite at Enslow, near Woodstock, and in the oolite at Stonesfield.

Teleosaurus Cadomensis (var.).—Of this species, which is nearly allied to, if not identical with *Cadomensis*, I have examined a posterior cervical vertebra from the oolite near Chipping Norton, now in the collection of Mr. Kingdon of that town. The sides of the centrum are less compressed than in the *Teleosaurus Chapmanni*, and the articular extremities have a more circular contour, the transverse exceeding the vertical diameter. There is no appearance of a ridge along the under surface: the transverse process of the centrum arises close to the neurapophysis.

	Inch.	Lines.
The length of this vertebra is	1	5
Transverse diameter of centrum	1	3
Vertical diameter of centrum	1	1½

Teleosaurus asthenodeirus, Nob.—If the cranium of this Saurian should correspond with the characters of the genus *Teleosaurus* which are exhibited by the vertebræ and scutes here described, a distinct species of this genus is very evidently indicated by them, characterized by the smaller size of the cervical ribs, and the consequently weaker structure of the neck.

In the Oxford Museum are preserved two cervical vertebræ and a dermal bone of this species, from the Kimmeridge clay at Shotover. The articular extremities and general form of the body of the vertebræ accord with the Teleosaurian type.

	Inches.	Lines.
The length of the centrum is..................	2	2
Vertical diameter of articular end	1	6
Transverse diameter of articular end............	1	5
Antero-posterior extent of lower transverse process	0	6

This process arises near the lower surface of the centrum, about half an inch from the anterior extremity of the bone. It is separated about the same distance from the upper transverse process, which is continued from the base of the neurapophysis; both the supports of the cervical rib are one-third smaller than the corresponding processes in the *Teleosauri Chapmanni* and *Cadomensis*, and are less extended from the sides of the vertebra.

The dermal scute is devoid of a ridge; one-half of the external surface is pitted with well-defined hemispherical depressions, separated from each other by about half their breadth, the smallest being nearest the margin; the other half of the scute is smooth, and indicates that it was overlapped by the adjoining scute, according to the characteristic disposition of this fish-like covering of the present extinct marine genus of Crocodilians.

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* I have much pleasure in expressing my thanks to S. Simpson, Esq., the Secretary of this excellent Institution, for the prompt acquiescence with my desire to have a section of these vertebræ made; and likewise to Thos. Satterthwaite, Esq., a member of the Society, for an accurate drawing of the fossil.

In the Hunterian Collection are two entire dorsal vertebræ, with part of a third, fractured through the middle of the body, and displaying a small cancellated cavity filled with calcareous spar, as in the *Teleosaurus Chapmanni*. These vertebræ present the slightly concave articular extremities, and the other characters of the genus *Teleosaurus*. The length of the centrum, measured along the under surface, is 2 inches 6 lines; vertical diameter of articular end 2 inches; transverse diameter 1 inch 10 lines; transverse diameter of the middle of the body 1 inch. Both the inferior and lateral surfaces of the body are regularly concave, lengthwise; and smooth, except near the expanded articular extremities, where they are striated in the axis of the vertebra.

The antero-posterior extent of the transverse process is 1 inch 6 lines; that of the base of the spinous process 1 inch 9 lines. The transverse diameter of the spinal canal 7 lines; its vertical diameter 4½ lines.

These vertebræ are cemented together by a matrix, which closely resembles the gray Kimmeridge clay; and a portion of a species of *Pecten* is attached, which is one of the characteristic fossils of the oolite group of secondary rocks, especially the Oxford clay.

STENEOSAURUS.

2de Gavial d'Honfleur, Cuv.

Steneosaurus rostro-minor, Geoffroy.

The generic name *Steneosaurus*, proposed by Geoffroy St. Hilaire for the Gavial-like Crocodilians with subterminal nostrils, but applied by him to species with vertebræ of two distinct systems, and altogether rejected by M. Hermann von Meyer, I propose to retain for that section of the Geoffroyan genus, including the species with vertebræ subconcave at both extremities, as in the genus *Teleosaurus*.

Remains of the genus *Steneosaurus*, thus defined, occur in the Kimmeridge clay at Shotover, and in the great or middle oolite.

I shall first describe a mutilated cranium from Shotover, preserved in the museum of Professor Buckland at Oxford. In this specimen the sides of the inter-temporal crest slope away, except at its anterior part, where it expands to one inch in breadth, and is convex; its longitudinal contour is slightly convex. The posterior boundary of the temporal fossa sinks below the level of the upper part of the cranium, and likewise terminates above in a sharp ridge, as in *Teleosaurus*. The ex-occipitals send out a transverse ridge, increasing in size to the mastoid process, below which there is a foramen: the cranial canal is cylindrical. The ex-occipitals so completely surround the posterior aperture of the cranium, that when the basi-occipital is displaced it remains entire. This is not the case in the *Teleosaurus*.

	Steneosaurus.		*Teleosaurus Chapmanni.*	
	Inches.	Lines.	Inches.	Lines.
Breadth of posterior part of cranium	11	0	5	6
From lower margin of condyle to inter-temporal ridge..............	4	8	2	4
Length of temporal fossa..........	5	0	2	6
Breadth of temporal fossa	5	0	2	0

In the upper jaw the teeth are closer together and relatively larger: there are 8 teeth in front of, and 27 behind, a short diastema: there is no groove along the inner side of the ramus of the jaw. In the lower jaw the post-articular angle is equal in length to the transverse diameter of the articular surface, approaching thus to Plesiosaurian proportions, whilst it is longer in the Gavial and in *Teleosaurus*. The articular surface is convex in the middle and concave on each side, as in the *Teleosaurus*, and not regularly concave, as in Gavial: the articular piece is continued more forwards, and is stronger upon the internal side of the ramus. The depth of the ramus at the coronoid ridge is greater, and the coronoid ridge itself is higher: there is no interspace between the angular and surangular elements*. From the angle to the beginning of the symphysis of the jaw is 1 foot 9 inches, the depth of the jaw at the coronoid process is 4 inches. The nostrils are bounded by short intermaxillaries, each of which contains three teeth. Both intermaxillary and maxillary teeth are larger in proportion than in *Teleosaurus*. The maxillary teeth are arranged closer together as they are placed further back. In a fragment of jaw containing three teeth, these are placed obliquely in sockets, from two to three lines apart. The fang is covered by a smooth white cement; the crown with a black enamel, traversed by fine longitudinal, close-set, interrupted ridges, one on each side of the tooth, is stronger than the rest, and meeting, in the unworn teeth, upon an obtuse summit.

In a fragment of a lower jaw of apparently the same species of *Steneosaurus*, in the Hunterian Collection, which includes 6 inches of the posterior commencement of the symphysis, the transverse diameter, at the junction of the rami, is 4 inches 3 lines: the middle of the posterior surface of the junction is excavated by a deep transversely elliptical depression. Both the upper and lower surfaces of this portion of jaw are flat, and the sides are nearly flat, and on right angles with the horizontal surfaces; the intervening angles being rounded off. The inner border of the alveolar tract is higher than the outer. The inferior flattened surface is impressed with some small, irregular, longitudinal vascular grooves, but not with pits or foramina. Eight teeth are contained in an extent of the alveolar tract measuring 5½ inches. The diameter of the circular base of the crown of the tooth is from four to five lines. The matrix appears to be oolite; the cavities in the crowns of the teeth are filled with white spar.

Perhaps the most interesting fact which has resulted from an examination of the British fossils of the present genus is the size and form of the brain, as exhibited by an internal cast of the cranial cavity.

In the museum of Professor Sedgwick there is a slab, in which the head of a *Steneosaurus* is imbedded, the upper part being exposed, from which a considerable part of the bony substance has been broken away, and, amongst the rest, the whole upper wall of the cranial cavity, exposing a tolerably perfect cast of its interior, which represents the brain of the extinct reptile. This cast resembles the smooth convex cerebral lobes of the Crocodile, and a portion of the large optic lobes which lie posterior to them. The cerebrum is 1½ inch in breadth, and the whole of the brain represented by this cast is 2 inches in length. The breadth of this head is 6½ inches. The temporal openings form wide ellipses, 2 inches 9 lines in the long diameter; from the back of the cranium to the commencement of the narrow elongated jaws is 8 inches; from these proportions the length of the individual may be calculated at about 18 feet.

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* In the thin, long and slender jaws ascribed to the *Poikilopleuron* by M. Deslongchamps, the coronoid is not raised, and there is an oblong vacuity between the angular and surangular.

POIKILOPLEURON BUCKLANDI, Eudes-Deslongchamps.

Nos. $\frac{294}{2294}$ and $\frac{295}{2295}$, in the Mantellian Collection, are the two moieties of a fossil caudal vertebra, fractured obliquely across the middle of the body, the length of which is to the breadth of its articular extremity as 3 to 2; both extremities are slightly concave; the body is gradually contracted from the two extremities towards the middle part; bears a transverse process developed from the posterior and upper part of its side, behind which there is a shallow groove; has the neural arch anchylosed, without trace of suture, to nearly the whole of the longitudinal extent of its upper surface. The neural arch is provided with anterior and posterior oblique processes, and a broad and thin spine developed at its posterior part, and strongly inclined backwards at its origin; lastly, the vertebra has a large medullary cavity in the centre of the body, filled, in the fossil, with spar. In all these particulars the Palæontologist acquainted with the excellent description by M. Eudes-Deslongchamps of the *Poikilopleuron Bucklandi*, from the oolite at Caen, will not fail to recognise the distinctive characters of that species in the present fossil. It is attached to a mass of the common Wealden stone, which is quarried at Tilgate, and was associated with the bones of the *Iguanodon*.

The length of the present vertebra is 3 inches 9 lines, or 9½ centimeters; that of the caudal vertebræ of the *Poikilopleuron* of Caen is about a decimeter*. We may conclude, therefore, that the individual from the Caen oolite and that from the Wealden were of the same size, and, from this correspondence, it is most likely that the size—25 French feet, which M. Deslongchamps assigns to the entire animal—is the common size of the species.

The vertical diameter of the articular end of the body of the Wealden vertebra is 2 inches 3 lines (5¾ centimeters); the transverse diameter of the same part is 2 inches 2 lines (5½ centimeters); the transverse diameter of the middle contracted part of the body is 1 inch 4 lines (3½ centimeters). The external free surface of the vertebra is almost smooth, being faintly marked by fine striæ. The form of the terminal surfaces of the centrum is a full ellipse, with its long diameter vertical. The longitudinal sulcus at the upper part of the side of the body is shallow, and slightly bent, with the convexity downwards; the base of the transverse process is continued from the upper boundary of the groove, and extends along the posterior half of the upper and lateral part of the centrum, and upon the base of the neural arch, which is here wider than the centrum: the transverse process is broken off near its origin. The base of the neurapophysis or side of the neural arch leaves only a very small portion of the upper part of the centrum free at its anterior and posterior part, to form the hole for the transmission of the spinal nerve: the distinction between the present genus and the *Cetiosaurus* is well marked in this respect. The neurapophyses have a less vertical extent than in the corresponding vertebræ of the *Cetiosaurus*, or even than in the Crocodile. From the upper part of the centrum to the upper edge of the anterior oblique process in a vertical line is only 1 inch, or about 2½ centimeters. The base of the spinous process is not thickest at its posterior margin, but gradually expands transversely as it extends forwards, and then, at a distance of 10 lines from its posterior part, it quickly contracts to a very thin plate, which is continued forwards to the conical depression at the interspace of the origin of the anterior oblique processes. The upper part of the spine is broken away, but the remaining base has the same backward inclination as in the Caen *Poikilopleuron*.

From the size and position of the transverse process, the Tilgate vertebra corresponds with the second or third of the first series of caudal vertebræ of the Caen *Poikilopleuron* figured by M. Deslongchamps. There is one character in the Wealden vertebra which is not mentioned in M. Deslongchamps' description of the Caen species, viz. a longitudinal sulcus at the middle of the under surface of the body of the vertebra, at least at its anterior half: the sulcus is not deep, and is 1 centimeter or 4 lines in breadth. The extremity of the under surface seems to be obliquely leveled off to form a single hæmapophysial surface. From this structure it might have been inferred that the hæmapophyses, which by their union form the chevron bone, were closely approximated, if not confluent at their bases, as in the *Iguanodon*; the Caen specimen, in which many of the chevron bones are preserved, proves this to have been the case. The fortunate fracture which demonstrates the peculiarly large medullary cavity in the centre of the vertebral body, gives the best proof that could be required of the generic identity of the Wealden vertebra with the Caen *Poikilopleuron*; and the absence of that cavity in the vertebræ of the *Megalosaurus*, which I have determined by a section of one of the caudal vertebræ, establishes the distinction between that genus and the *Poikilopleuron*.

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* "Nos vertebrès ont chacune environ un décimètre de long."—Deslongchamps, *l. c.*, p. 53.

In the form of its sub-biconcave vertebræ, and the simplicity of their neural arch as compared with the *Streptospondylus* and the *Dinosaurians*, the *Poikilopleuron* manifests its closer affinity to the Cœlospondylian Crocodiles. It agrees with the *Teleosaurus* in the comparative shortness of the fore legs; the mode of articulation of the vertebral ribs appears to be the same, and there is no evidence that it differs in the structure of the abdominal ribs.

The number of caudal vertebræ would appear to be greater; but I know not in what material respect the *Poikilopleuron* resembles the Lizard tribe more closely than does the *Teleosaurus*, unless it should be proved to have five toes on the hind foot, and to want the dermal armour. Subsequent discoveries may prove it to belong, like the *Megalosaurus*, to the *Dinosaurian* order; but as the *Poikilopleuron* is at present known, it seems to have most claim to be received into the *Cœlospondylian* family of the *Crocodilian* order, and perhaps has the closest affinity in that family to the *Crocodilus Bollensis*, Jaeger (*Macrospondylus*, H. v. Meyer).

To the genus *Poikilopleuron* it is most probable that the specimen No. $\frac{141}{2141}$ in the Mantellian Collection belongs, as it agrees in size, in texture, and especially in the character of the external surface with the caudal vertebra last described. As it consists of the annular part or neural arch only, the test of the medullary cavity of the body cannot be applied. It belongs to one of the anterior dorsal vertebræ, and is distinguished by well-marked and peculiar characters from the corresponding vertebræ of the *Iguanodon*, *Megalosaurus*, *Hylæosaurus*, *Cetiosaurus*, and *Streptospondylus*; and in the chief of these differences it approximates to the sub-biconcave Crocodilian type of vertebræ. As only the caudal vertebræ of the *Poikilopleuron* appear to have been hitherto discovered, I cannot avail myself of the aid, in the determination of the present fossil, which the able descriptions of M. Deslongchamps afforded in reference to the preceding one; there remains, therefore, to record the characters of the present fragment of a dorsal vertebra, in order that they may be compared with more perfect ones from the oolite of *Maladrerie* near Caen, in the event of the remainder of the vertebral column of the *Poikilopleuron* ever falling into the hands of the Palæontologist.

The present fossil is imbedded in the ferruginous sand of the Tilgate strata; its antero-posterior diameter from the extremity of the anterior to that of the posterior oblique process, is 5 inches 4 lines.

The neurapophyses, instead of rising and expanding to form a broad platform to support the spinous process, as in the *Dinosaurian* vertebræ of the Wealden, converge rapidly above the spinal canal, and support the spinous and transverse processes by a longitudinal plate not more than from 3 to 6 lines in transverse thickness; from each side of this plate a horizontal, flat, broad, lamelliform transverse process, supported below by a subvertical triangular plate, extends outwards and a little upwards; and a broad, thin, and moderately high spinous process arises, in a peculiar manner, by two laminæ, from the whole antero-posterior extent of the ridge-like summit of the neural arch. The fossil is broken in two; a portion of the centrum adheres to the anterior part of the neural arch, demonstrating the anchylosis of the two parts without trace of suture. In this respect the fossil agrees with *Poikilopleuron* and differs from *Iguanodon*, in which the neural arch is anchylosed with the centrum, but evident traces of the suture remain, at least in the dorsal vertebræ. The anterior part of the side of the centrum is impressed by a large surface for the head of the rib; the surface is concave in the axis of the vertebra, convex vertically, and is bounded above by a well-defined ridge.

The anterior oblique processes support flat articular surfaces of an elliptical form, 16 lines by 9 lines, looking upwards and inwards, their lower edges converging at an angle of 50°. These edges are separated from each other by a fissure 3½ lines broad, continued to the base of the anterior oblique processes. In the *Iguanodon* the corresponding surfaces incline to each other at a right angle, and the lower margins of the processes are united by a continuous tract of bone. The present fossil, in the above-cited particular, resembles more the *Cetiosaurus*. Each anterior articular surface is supported by a stout process convex externally, inclining forwards and slightly expanding, so as to overhang and extend in a slight degree beyond the anterior end of the centrum: these processes are relatively lower than in the *Iguanodon*, in which also they do not extend beyond the centrum: the present fossil, in differing in these two respects from the *Iguanodon*, indicates characters which are exaggerated in the caudal vertebræ of the *Iguanodon*. A deep and narrow excavation commences immediately behind the upper and posterior origins of the anterior oblique processes, and is continued backwards, increasing in vertical extent, deep into the anterior part of the base of the spinous process. Immediately behind the columnar portion of the anterior oblique process a deep and wide conical cavity sinks, as it were, into the neurapophysis, undermining the anterior part of the base of the transverse process, and dividing the anterior oblique process from the supporting plate of the transverse process.

The transverse process commences from the summit of the neurapophysis immediately exterior to the anterior part of the base of the spinous process, by a ridge which is continued backwards from the upper and outer margin of the anterior oblique process, in a gentle curve outwards and slightly upwards. The posterior margin of the base of the transverse process is not continued, in like manner, into the posterior oblique process, but terminates or subsides into a ridge above, and separated from that process by a wide groove.

The bases of the two transverse processes are only separated from each other, owing to the modification of the neural arch above mentioned, by a thickness of bone not exceeding 4 lines: the interspace of the origins of the two transverse processes in a corresponding vertebra of the *Iguanodon* measures 4 inches; the length of the base of the neural arch being the same in the vertebræ compared.

The antero-posterior extent of the base of the transverse process in this (presumed) vertebra of the *Poikilopleuron* is 2 inches 2 lines. The length of the transverse process is 4 inches. The vertical diameter, or thickness of the transverse process, where unsupported, is from 2 to 3 lines. It is obvious, therefore, that this long, thin, lamelliform plate of bone must need further support, in order to sustain the rib which is appended by its tubercle to the extremity; and the requisite strength is here given precisely as the carpenter supports a shelf by a bracket. The bracket-like process is a vertical triangular plate of bone, the breadth or depth of which, at its origin, is 1 inch 4 lines, and which gradually diminishes in depth and increases in thickness as it extends along the middle of the under part of the transverse process, until it is finally lost near the extremity of the process, which here has exchanged its lamellar for a prismatic form, terminating in the obtuse extremity against which the tubercle of the rib abutted. The supporting bracket is not quite vertical, but inclines a little forwards, and behind it there is a deep angular fossa. The posterior oblique processes diverge from each other and from the neural arch immediately above the posterior extremity of the spinal canal: each articular surface, which is directed downwards and outwards, forms, as it were, the base of a posterior root of the spinous process, which is convex externally, diminishing in breadth as it converges to meet its fellow at a very acute angle above a deep fissure extending forwards into the substance of the base of the spine, similarly to the fissure before described as extending backwards from the opposite part of the spine into its substance. As far as I could detach the matrix, these fissures extended so that they seem to communicate, and the neural arch to be perforated by two longitudinal passages, one for the spinal chord, and the other, running above and parallel with the former, through the base of the spinous process. This process is thus partially separated at its base into two laminæ, and presents a structure which almost realizes Prof. Geoffroy's theoretical idea of the essential nature of a spinous process, viz. that it consists of two elementary laminæ, which in fishes are superimposed one on the other, but in other Vertebrates are placed in juxtaposition.

The anterior parts of each spinal plate are thickened and rounded, like those behind, and extend to the origins of the anterior oblique processes. The diameter of this remarkable spinal fissure is from 4 to 3 lines. It is present in an inferior degree in the *Teleosaurus*, but not in the vertebræ of the *Iguanodon*, *Megalosaurus*, or other *Dinosauria*.

The base of the spinous process in this (presumed) Poikilopleuron's vertebra, instead of descending from behind forwards in a graceful curve, as in the *Dinosaurs*, forms a straight and almost horizontal line, 3 inches in extent: the spine maintains the same breadth to its summit, which is truncated rather obliquely; its height is 4 inches 9 lines, measured from the upper end of the posterior oblique processes; it is thickened and rounded at its truncate summit. The height of the spine of a corresponding vertebra of the *Iguanodon*, with a centrum of the same length, is 9 inches. Thus the present vertebra more resembles, in the form and proportions of its spinous process, as in other characters, the vertebræ of the Crocodilians.

The posterior part of the neural arch, with the spinous process of the vertebra here described, is figured in Dr. Mantell's 'Illustrations of the Geology of Sussex,' pl. xii. fig. 1, as the 'Lumbar Vertebra of the *Iguanodon*.' It is unquestionably not a lumbar vertebra; and if it does not belong to the *Poikilopleuron*, it indicates an unknown genus of Crocodilians.

In a collection of fossils belonging to S. H. Christie, Esq., from the submerged Wealden beds near the Isle of Wight, there is one half of the centrum of a dorsal vertebra from Brook Bay, which agrees in size, in the form of the articular extremity, in the degree of median constriction, and, especially, in the large size of the medullary cavity at the middle of the bone, with the vertebral characters of the *Poikilopleuron*.

STREPTOSPONDYLUS, H. von Meyer.

Steneosaurus rostro-major, Geoffroy.—1*re Gavial d'Honfleur*, Cuv. (*vertebræ*.)

I am not aware that remains of this Crocodilian genus have hitherto been recognised in any of the British strata. The very characteristic vertebræ and jaws, of which the singular generic modifications were first described by Cuvier,[*] were found in the Oxford clay formation at Honfleur, and in the Kimmeridge clay at Havre. M. Hermann von Meyer likewise cites the lias of Altdorf as a depository of the fossil bones of this genus[†].

The distinguishing vertebral characters are a ball and socket articulation of the bodies of the vertebræ; but the positions of the ball and cavity are the reverse of those in the existing Crocodiles, the convexity being on the anterior part of the vertebra, and the concavity directed backwards. In the anterior vertebræ, which have the ribs articulated with the body, there is a deep pit behind the costal articular surface; the transverse process rises by four salient ridges, one from each oblique process, and the two inferior and principal ones from the base of the neurapophysis; these ridges converge at an acute angle as they ascend, and meet at the under part of the transverse process, so as to include a triangular space, which is deeply concave. A third salient ridge ascends from the fore part of the base of the neurapophysis to the anterior oblique process, nearly parallel with the posterior of the two last-mentioned ridges, so that the side of each neurapophysis appears as if marked with the letter N in high relief. In the cervical and anterior dorsal vertebræ there are, instead of a single inferior spinous process, two ridges which terminate each, in front, by a tubercle, as in the vertebra dentata of the Crocodile.

Streptospondylus Cuvieri, nob.—The first fossil here to be noticed, which combines any of the above defined characters, is the anterior half of an anterior dorsal vertebra, in the collection of Mr. Kingdon of Chipping Norton: it was found in the oolite in the vicinity of that town.

The articular surfaces for the ribs are, as usual, close to the anterior part of the body of the vertebra, and this terminates by a convex articular surface, instead of being, as in the Crocodiles, concave: the second character is the remarkably deep pit behind each of the costal articular surfaces. It is as if a man had pressed his two thumbs forwards and inwards up to the first joint, into the substance of the body of the vertebra, until their extremities had nearly met. The aperture of each pit measures 1 inch by 10 lines. Sufficient of the neurapophysial arch is preserved to show the depression which has separated the two anterior ridges of its external surface; but these characteristic ridges, with the transverse, spinous and oblique processes, are broken away. The medullary canal is compressed, and gives an oval vertical section, 1 inch 6 lines high, and 1 inch 2 lines wide. Both upper and lower surfaces of the medullary canal are flat, and join the lateral surfaces at nearly a right angle. There is a slight ridge along each side of the medullary canal, indicating the neurapophysial suture, which extends here outwards and obliquely downwards to above the middle of the costal depression. This depression is vertically ovate, with a deeper oblique pit in the middle, 2 inches in the long diameter, by 1 inch 6 lines across the broadest part. The texture of this vertebra is coarsely cellular, except for about two lines at the margin, where it is in very compact laminæ. The anterior articular surface of the centrum is slightly and irregularly convex, being nearly flat at the upper part.

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[*] Ann. du Mus. xii. p. 83, pl. x. xi.

[†] The Saurian remains to which Prof. Bronn ('Lethæa Geognostica,' 1837, 8vo) has attached the name of *Leptocranius*, cannot belong, as he supposes, to the present genus, if it be true that the vertebræ are slightly constricted in the middle, and have both articular extremities concave, as in the following description:—"Die dazu gehorenden Wirbel-Korper in der mitte wenig verengt, vorn und hinten sind concave Gelenk-flache."—p. 517.

There is a slight deviation from the symmetrical figure in the whole of this vertebral fragment. The body of the vertebra is much contracted in the middle, and suddenly expands to form the terminal articular surface. This character is likewise indicated by Cuvier in his *Crocodile d'Honfleur**; thus the transverse diameter of the middle of the vertebral body, across which the present fossil has been fractured, measures 2 inches 3 lines, whilst the same diameter of the convex articular extremity is 4 inches.

The corresponding diameters of one of the anterior dorsal vertebræ of the *Streptospondylus*, described by Cuvier, are respectively 1 inch 7 lines, and 2 inches 6 lines; whence we may conjecture that the length of the entire vertebra here described would have been 4 inches and a half. The vertical diameter of the articular surface is 3 inches 9 lines.

The non-articular surface of the vertebral body is smooth, except near the articular extremity, where it is rather coarsely rugous. The inferior ridges and tubercles have disappeared at the part of the vertebral column to which the present vertebra has belonged.

The osseous substance of the present fossil, like that of the bones of the *Streptospondylus* from Honfleur, presents a deep chocolate brown hue, and takes a bright polish. It is not completely mineralized; the small cavities of a great part of the diploë are empty, and not filled with semitransparent calcareous spar, as in the Honfleur specimens.

With the portion of the vertebra above described there was associated the extremity of a spinous process, which gradually expands to a rough obtuse quadrilateral summit. This spine is characterized by having a very rugged and thick ridge, developed from the anterior and posterior surface of what may be regarded as the ordinary spinous process, the sides of which are smooth, except near the summit.

	Inches.	Lines.
The length of this fragment of spine is	3	8
The transverse diameter of the base	0	9
The transverse diameter of the summit of the apex	1	6
Antero-posterior diameter of spine	1	3
Ditto, including the ridges	1	10

In the Crocodile a thin plate is continued from the anterior and posterior edges of the thicker spinous processes; but the *Streptospondylus*, if I am correct in attributing this spinous process to that genus, presents an extreme and peculiar development of this structure.

A portion of a compressed, conical, hollow tooth, with a brown dense glistening dentine, covered by smooth enamel, and resembling that of the *Megalosaurus*, was associated with the preceding vertebra. The length of this fragment of tooth is 2 inches 4 lines, but both ends are wanting. The breadth is 8 lines; the thickness 5 lines†. If it really belong to the *Streptospondylus*, it confirms the view of the affinity of that genus to *Megalosaurus*, which has been suggested by the characters of the vertebra. With the above fractured vertebra and tooth there were likewise found, in the oolite at Chipping

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* "Le corps de cette vertèbre, ainsi que des suivantes, est beaucoup plus rétréci dans son milieu que dans les Crocodiles connus."—Ossem. Foss. ed. 1824, tom. v. pt. 2. p. 156.

† The teeth conjectured by Cuvier to belong to the *Honfleur Streptospondylus* are conical and striated.

Norton, a portion of a broad flat bone, with a convex, rough, articular labrum, nearly two inches thick, and of a fine cancellous structure, and fragments of long bones, with large medullary cavities and compact outer walls, of which the thickness equals about one-third of the diameter of the medullary canal.

A more perfect specimen, referable to the present genus, is a posterior dorsal vertebra from the jet-rock (lias shale) near Whitby, and forms part of the collection of fossils of Mr. Ripley, surgeon of that town.

It is much more complete than the preceding specimen, wanting only the spinous and transverse processes; there is a slightly raised oval surface for the articulation of the head of the rib, on each side of the body, at its upper and anterior part, in the corresponding situation with that for the head of the rib on the four anterior dorsal vertebræ in the existing Crocodiles: this surface in the Whitby vertebra is relatively smaller and lower down than in the larger specimen of *Streptospondylus* from the oolite.

The present specimen nearly corresponds in size with the dorsal vertebræ of the Honfleur *Streptospondylus* described by Cuvier*, as will be seen by the following admeasurements:—

	Whitby.		Honfleur.	
	Inches.	Lines.	Inches.	Lines.
Length, or antero-posterior diameter of body .	3	5	3	8
Transverse diameter of articular surface . . .	3	0	3	3
Transverse diameter of middle of body . . .	1	3	1	6

The principal character of the vertebræ of *Streptospondylus*, viz. the anterior ball and posterior cup, is unequivocally demonstrated in this specimen by the presence of the oblique processes, which determine the anterior and posterior extremities of the vertebra; the two articular surfaces which look upwards and inwards correspond with the convex extremity of the body of the vertebra; while those on the oblique processes, which look downwards and outwards, overhang the extremity of the body of the vertebra, which is excavated by a moderately deep and regular concavity.

To judge from the figures of two of the vertebræ of the *Streptospondylus*† from Honfleur, the characteristic fossa on each side of the body becomes shallower, and situated nearer the middle of the side of the body as the vertebræ approach the tail; but the lateral fossæ present both these modifications in the Whitby vertebra, which, from the articular surface of the rib, would seem to have come from the anterior part of the dorsal region of the spine.

This vertebra presents the minor generic characters of the *Streptospondylus* in the length of the body, its lateral compression and inferior concavity, the two extremities being expanded to form the articular surfaces. The non-articular surface is smooth, except near the margins of the articular extremities. The line of the hæmapophysial suture extends horizontally the whole length of the centrum. The two characteristic lateral buttress-like ridges rise from the two extremities of the base of the neurapophysis, and converge to the under part of the base of the transverse process, where they meet; the depressions between and on each side of these ridges are deep: the third ridge extending from the anterior part of the base of the neurapophysis to the anterior oblique process stands out in nearly as bold relief as those which support the transverse process.

The articular surfaces on the oblique processes are bounded by a regular convex free margin; their long diameter is 1 inch 10 lines, their short diameter 9 lines; they are nearly flat: the anterior ones look inwards and upwards; the posterior downwards and outwards.

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* *Loc. cit.*, p. 308.

† Ossem. Foss. v. pl. ix. fig. 3 and 10.

The two superior ridges, extending from the upper part of the anterior and posterior oblique processes to the transverse process of the same side, describe a regular concave curve.

The vertical diameter of the fractured transverse process is 1 inch 3 lines, its transverse diameter is 1 inch.

The great development of the superior part of the neural arch, and the strength and high relief of the buttress-like ridges supporting and strengthening the different processes, indicate that the spinous process was unusually large and massive. This process was not preserved in any of the vertebræ of the Honfleur *Streptospondylus* described by Cuvier, nor, unfortunately, in the present vertebra; but its otherwise more perfect state adds another character to those by which the vertebræ of the *Streptospondylus* deviate from the Crocodilian type; viz. a broad plate of bone extended transversely between the two posterior oblique processes, and increasing in breadth as it ascends. The base from which the spinous process should rise, which is thus bounded by the oblique and transverse processes, extends beyond, and, as it were, overhangs the whole body of the vertebra below; and is hardly less remarkable for the height to which it is carried above the body.

Thus from the highest part of the posterior oblique process to the lower margin of the corresponding articular surface of the vertebral centre measures 6 inches; the length of the vertebral centrum being 3 inches 5 lines: the contrary proportions prevail in the posterior dorsal and lumbar vertebræ of the existing Crocodiles. The breadth of the neural arch, where the lateral buttresses terminate at the base of the transverse processes, is 6 inches.

Streptospondylus major, nob.—The third British formation in which I have determined the remains of the genus *Streptospondylus* is the Wealden; the specimens having been obtained from three localities, viz. Tilgate Forest in Sussex, and Brook Point and Culver Cliff in the Isle of Wight. The specimens differ in size from those already described, being larger than the *Streptospondylus Cuvieri* from the oolite; I strongly suspect that they indicate a distinct species, but the means of comparison for the satisfactory establishment of the distinctions are as yet wanting. M. H. von Meyer has added nothing but the generic name to the observations of Cuvier, on which the claims of the present extinct Crocodilian to generic distinction are founded: these observations were taken from the dorsal vertebræ, atlas and axis, whilst the most characteristic of the Wealden vertebræ appertain to the middle part of the cervical region, from whence vertebræ of the reversed ball and socket system have not been hitherto recognized.

These vertebræ I apprehend to be those on which Dr. Mantell has founded his description of the "Fourth system" from the Wealden. He says, "The vertebræ of the fourth system (fig. 4) are very rare, only six or seven have come under my observation. They are of the true Lacertian type, having the articular facets of the body convex posteriorly and concave anteriorly, and are *wider than high*, as in the Iguana and Monitors, and not in the reverse proportions, as in the recent Crocodiles. In two large but mutilated cervicals, the admeasurements are as follow:—

	Inch.
"Height of the concave extremity	3½
Width of the same	4½
Length of the body	6

"It is not obvious whether the annular part be divided by suture or otherwise; the articular apophyses are horizontal and very strong; the spinous process is destroyed *."

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* Mantell's Geology of the South-east of England, 8vo, 1833, p. 300.

It is the fortunate preservation of the two articular, or oblique processes, at one of the extremities of the annular part of this fine cervical vertebra, now in the Mantellian Collection, British Museum (No. $\frac{116}{2116}$), that has enabled me to correct the error into which the Founder of that noble collection has, in this instance, fallen: the flat oblong articular surface of each of these strong and well-marked oblique processes looks downwards and outwards, determining them to be the *posterior* pair; and they overhang the concave extremity of the body of the vertebra, determining that to be the *posterior* extremity. The opposite, or *anterior* end of the body of the same fossil, is convex. The few other large convexo-concave vertebræ from the Wealden of Tilgate correspond with the one here described in these important characters of the genus *Streptospondylus*, and equally differ from the vertebræ of the *Iguanæ*, *Monitors*, and all other existing *Sauria*. Of the fossil cervical vertebra, 6 inches long, the anterior extremity of the body is further indicated by the position of the costal tubercle, or transverse process, which is developed as a strong obtuse ridge from the middle part of that half of the centrum which is nearest the convex articulation. Beneath this ridge the sides of the body are concave, and converge to a broad ridge, which terminates the anterior part of the lower surface of the vertebra, and corresponds with the process given off from that part in the cervical vertebræ of the Crocodile. A second concavity, at the upper part of the side of the body, separates the transverse process, or ridge, from the base of the neural arch; from which a second, or upper transverse process is developed for the attachment of the tubercle of the rib.

The neural arch has been crushed down upon the centrum, and its anterior oblique processes and spine are broken away; the upper, non-articular part of the strong diverging posterior oblique processes is convex.

In the museum of Mr. Saull, F.G.S., Aldersgate Street, there is a cervical vertebra of the great *Streptospondylus* associated, as in the Mantellian Collection, with vertebræ of the *Iguanodon* and *Cetiosaurus*, all of which have been washed out of the submarine Wealden beds at the south side of the Isle of Wight, and thrown on shore near Culver Cliffs and Brook Point.

The lower half of the sides of the centrum of the vertebra of the *Streptospondylus* are, like the preceding vertebra from Tilgate, concave and obliquely compressed, so as to converge to the anterior part of the under surface, which thus presents a triangular form, with the apex forming the obtuse anterior ridge, and the base turned backward and somewhat flattened. Each lateral concavity is bounded above by a short but broad transverse process, developed from the anterior half of that part of the centrum, and terminated by an oblong flattened surface for the articulation of the head of the cervical rib; which surface is about twice as long in the antero-posterior as the vertical direction. Above this process the centrum is again concave. The base of the neurapophysis is anchylosed to nearly the whole antero-posterior extent of the centrum, the course of the original straight suture being readily discernible. An upper transverse process is developed from the side of the base of the neurapophysis, affording a broader surface for the tubercle of the cervical rib than does the lower transverse process. Above the upper transverse process the neurapophyses converge obliquely to the base of the spinous process. The line of the base of the spine inclines forwards, and the thickness of the spine diminishes in the same direction. The difference in the height of the neural arch, and in the configuration of its external surface, which both the cervical vertebræ of the great Wealden *Streptospondylus* present, when compared with the dorsal vertebræ of the smaller specimens from the older oolite formations, is very great; and the more remarkable, as in the existing Crocodiles the height of the neurapophyses is greater in the cervical than in the dorsal region: as, however, the transverse processes in the Crocodiles come off from a higher part of the neural arch in the dorsal than in the cervical vertebræ, the spine of the great Wealden *Streptospondylus* may possibly present modifications in the dorsal region corresponding with those remarkable ones which have been already described in the Whitby vertebra.

The posterior articular processes in the cervical vertebra from Culver Point, are similar in all respects to those in the Tilgate specimen, and equally determine the fore and hind extremities of the vertebra.

The following are admeasurements of the bodies of the two vertebræ of the Wealden *Streptospondylus*:—

	Tilgate.		Culver Cliff.	
	Inch.	Lines.	Inch.	Lines.
Transverse diameter of posterior concave articular surface	5	0	6	0
Vertical diameter of posterior concave articular surface	3	6	4	6
Antero-posterior diameter	6	0	5*	0
Transverse diameter of the body across the inferior transverse processes . . .	6	0	6	6
Height from lower surface of centrum to the hind part of base of spine . .			7	9
Antero-posterior extent of lower transverse process	2	2	2	4
Interspace between upper and lower transverse processes			2	0

In the museum of the Geological Society of London there is a collection of rolled vertebræ from the coast at Brook Point, Isle of Wight, which, among the bones of *Iguanodon* and other gigantic Wealden genera, contains the centrum or body of a dorsal vertebra of the great *Streptospondylus*. This specimen, though much rolled and worn, is interesting, inasmuch as it exhibits the characteristic contraction of the middle and expansion of the ends of the centrum, together with unequivocal evidences of the marked depression on each side, near the upper part of the anterior or convex end of the centrum. What remains of the depression is about the size of the end of a man's thumb. The convexity of the anterior extremity resembles in degree, and likewise in irregularity, that in the fractured vertebra of the *Streptospondylus* from the oolite, in Mr. Kingdon's collection.

The present centrum is less depressed than those of the cervical region, but agrees with them in length, as the following dimensions show:—

	Inches.	Lines.
Antero-posterior diameter	5†	0
Vertical diameter of concave end	5	6
Transverse diameter of concave end . . .	5	3
Transverse diameter of middle of centrum .	3	0

The vertebra from the forest marble alluded to in the note at p. 297 of Dr. Mantell's 'Geology of the South-east of England,' is a centrum from the posterior part of the dorsal region of the *Streptospondylus major*.

The determination of the true nature of the convexo-concave vertebræ of the Wealden, and of the affinities of the reptile to which they belonged, besides extending our knowledge of the gigantic oviparous animals of that

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[*] It is evident that an inch at least, perhaps more, has been chiseled away from the ball which terminated the anterior end of the body of the specimen in Mr. Saull's collection.

[†] The margins of the extremities being worn and rounded prevent the actual length being given.

epoch, removes one of the chief difficulties attending the determination of the true vertebral characters of the *Iguanodon*. For if gigantic vertebræ, agreeing in the important character of their articular surfaces with the existing *Iguanæ*, had actually been discovered, though of rare occurrence, associated with teeth of corresponding dimensions, but similar in form to those of the Iguana, there would have been strong ground for suspicion, that such vertebræ and teeth might be parts of the same species *

The elimination of these, otherwise perplexing, ball and socket-jointed vertebræ, and their identification with the peculiar Crocodilian genus of Honfleur, on which M. H. von Meyer has imposed the name of *Streptospondylus*, forms, therefore, an essential step in the appropriation to the *Iguanodon* of its true vertebral characters.

CETIOSAURUS.

Cetiosaurus brevis, nob.—The attempt to reduce to order the various forms and types of vertebræ, which the Wealden strata have yielded to test the sagacity of the interpreters of its organized treasures, was one of Dr. Mantell's earliest labours, and he states † that his first step was, with the able assistance of the Rev. W. D. Conybeare, to separate those that belonged to the Crocodile, *Plesiosaurus* and *Megalosaurus*, or rather which resembled those from Stonesfield. Many enormous vertebræ then remained, from which those belonging to the *Iguanodon* were to be chosen; from these residuary specimens the characteristic ones of the *Poikilopleuron* and *Streptospondylus* have already been eliminated, and I next proceed to remove from them the vertebræ which characterize the genus *Cetiosaurus*.

Of the existence of vertebræ of this genus in the Wealden strata, I first became acquainted by the examination of Mr. Saull's collection of sea-rolled fossils washed out of the submerged Wealden beds, and deposited on the shores of the Isle of Wight, at Sandover Bay.

The vertebræ in question present the well-marked generic characters of those of the dorsal region in the *Cetiosaurus*, as the breadth of the centrum, its subcircular contour, its median contraction and unequal concavity of the articular extremities; as, also, the short antero-posterior extent of the neurapophysis, and their anchylosis to the anterior part of the upper surface of the centrum: but they differ from the vertebræ on which the characters of the present genus were first founded ‡ by the shortness of their antero-posterior diameters as compared with their breadth and depth, whence I propose to designate the species by the name of *Cetiosaurus brevis*.

The centrum of a dorsal vertebra of this species from Culver Cliff measures,

	In.	Lines.
in antero-posterior diameter	3	6
transverse diameter	6	4
vertical diameter	6	0

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* This suspicion is expressed, but with due caution, by Dr. Mantell in his 'Geology of the South-east of England.' "The somewhat angular vertebræ, described as appearing to constitute a Second System, I should be disposed, from their number, and from their so commonly occurring in the localities where the teeth of the *Iguanodon* most abound, to refer to that animal; it must, however, be mentioned, that the concavo-convex vertebræ which correspond so entirely with those of the Iguana and Monitor, would seem to offer a more probable approximation; yet the extreme rarity of the latter renders it questionable, since there appears no reason why the vertebræ should not have been preserved in as considerable numbers as the teeth."—p. 306. The vertebræ of the *Iguanodon* discovered by Mr. Benstead in the greensand quarries near Maidstone, are so crushed or so imbedded, as to prevent a satisfactory determination of both articular extremities.

† Illustrations of the Geology of Sussex, 4to, 1827, p. 76. Geology of the South-east of England, 8vo, 1833, p. 278.

‡ See Proceedings of the Geological Society for June 1841.

One of the articular ends * is rather more concave than the other, which, from the wearing away of the margins, appears slightly and unevenly convex. The contracted middle part of the vertebra is concave lengthwise, and pretty regularly convex in the direction transverse to the axis of the vertebra; the free surface is finely striated, and perforated here and there by vascular foramina; there is no lateral depression. The neurapophyses were broken off; their bases, instead of having their long diameter corresponding with the axis of the vertebra, as in *Iguanodon*, present it in the direction transverse to that axis, as in *Plesiosaurus*: they do not quite meet at the middle of the upper or neural surface of the centrum, but are there divided by a narrow longitudinal tract forming the lower part of the spinal canal.

The antero-posterior extent of the anchylosed base of the neural arch is 2 inches 6 lines: the transverse diameter, 5 inches.

Two caudal vertebræ of the same species, also from Culver Cliff, present the same length and unequal concavity of the articular extremities; the anterior one, here determinable by the anterior position of the narrower hæmapophyses, being the deepest: the sides of the body are more compressed, and more convergent towards the under surface; so that, as the expanded margins of the articular ends are worn away, the centrum presents rather a triangular than a subcircular contour. The disproportion of its antero-posterior with its transverse and vertical diameters, distinguishes it from the caudal vertebræ of the *Iguanodon*. The neurapophysis rises from the anterior three-fourths of the centrum, and sends forwards a subprismatic anterior oblique process, but does not develope a posterior one: it then contracts, and inclines to the base of the spine, which is much shorter than in the *Iguanodon*. The spinous process inclines backwards from the vertical axis of the centrum at an angle of 45°. A short transverse process is developed from the junction of the neurapophysis with the centrum. The hæmapophysial surfaces appear single on both the anterior and posterior parts of the lower surface; they are nearly flat, and slope towards each other.

	In.	Lin.
Antero-posterior diameter	3	0
Transverse diameter	5	0
Vertical diameter	5	0
Height of vertebra to summit of spine† .	12	9
Antero-posterior diameter of spine . . .	2	10
Thickness at posterior part of base . . .	1	0
Height of spine, 1st caudal	5	0
Height of spine, 2nd caudal‡	4	0

The characters and dimensions of these rolled vertebræ of *Cetiosaurus* from the submarine beds of the Wealden formation, although somewhat obscured by the circumstances under which they are brought to light, are sufficiently satisfactory to establish their generic character, and to give an useful approximative idea of their size and proportions. The corresponding bones from the Wealden of Tilgate Forest supply, by their more perfect state of preservation, the deficiencies of the Isle of Wight specimens, and further establish the co-existence of the *Cetiosaurus* with the *Iguanodon*, *Streptospondylus*, *Megalosaurus* and other extraordinary reptiles of that period. The vertebræ of the *Cetiosaurus brevis* in the Mantellian Collection are the most gigantic specimens of Saurian remains that enrich it. They include the bodies of two dorsal vertebræ and four entire caudal vertebræ, which, if not consecutive, seem to have come not from distant parts of the basal portion of the tail of the same individual; there are also the bodies of several of the smaller posterior caudal vertebræ.

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* Subsequently determined by more perfect specimens to be the posterior surface.

† This is rounded off, but seems not to have been broken.

‡ The 1st and 2nd do not here refer to the place of these vertebræ in the tail; but if the vertebræ were contiguous in the entire animal, the tail must be much shorter than in the *Iguanodon*.

No. $\frac{133}{2133}$ ("Gigantic vertebra of *Iguanodon*," MS. Catalogue of Mantellian Collection,) is a posterior dorsal vertebra of the *Cetiosaurus brevis*, and exhibits in a striking manner the peculiar characters of this species, viz. the great depth and breadth, especially the latter dimension, as compared with the length or antero-posterior diameter of the centrum or body of the vertebra.

The posterior articular facet is, in this region of the spine, more concave than the anterior surface, a structure which approximates to that peculiar one which characterizes the *Streptospondylus* *. The contour of the articular ends is a full transverse oval: the middle of the centrum is strongly contracted, slightly concave in the longitudinal direction at the upper part of the side of the centrum, but deeply concave below, and with a slight indication of a broad, obtuse longitudinal ridge along the middle of the concave under surface. In the *Iguanodon* the sides of the vertebral body are nearly flat in the vertical direction; in the *Cetiosaurus* they are strongly convex. The surface at the middle of the vertebra is longitudinally striated with very fine, subparallel, short impressions: these grow deeper and more irregular at the thick, rugged and everted margins of the articular ends.

The neurapophyses are firmly anchylosed here, as in the caudal region, and the line of the primitive suture is hardly discernible: their base is shorter than the short centrum, and is attached nearer its anterior part: in the *Iguanodon* the neural arch is very nearly coextensive in antero-posterior diameter with the centrum supporting it: in a dorsal vertebra, of an *Iguanodon* 4½ inches in breadth, the antero-posterior extent of the base of the neural arch is 4 inches: in the present vertebra, which exceeds 7 inches in breadth, the antero-posterior extent of the base of the neural arch is 2½ inches, and only 2 inches a little above the base. The outer side of the neurapophysis is convex in the axis of the vertebra, and concave in the opposite direction as it ascends to the base of the transverse process, without exhibiting a trace of the ridges and hollows that so singularly characterize the same part in the dorsal vertebræ of the *Streptospondylus Cuvieri*. The antero-posterior diameter of the base of the transverse process is 2 inches; its vertical diameter 1 inch. The diameter of the spinal canal is 1 inch 9 lines. The articular surfaces of the anterior oblique processes are flat, and look upwards and slightly inwards. In the *Iguanodon* their under margins, in the dorsal vertebræ, converge at nearly a right angle: in the present vertebra they incline to each other at an angle of 40°. The spinous process begins to rise immediately behind the anterior oblique processes by a narrow vertical plate, which seems as if it were nipped in between two shallow depressions; its base ascends obliquely, and grows thicker to the posterior part of the neural arch. The summit is not entire.

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* Since the vertebræ of the *Streptospondylus* lose their peculiar convexo-concave character by the gradual subsidence of the anterior ball, as they approach the tail, the cervical vertebræ of the *Cetiosaurus* may approach, more nearly than do the dorsal ones, to the convexo-concave structure of the Streptospondylian vertebræ. The fact that, hitherto, only cervical vertebræ of the great *Streptospondylus*, and only dorsal and caudal vertebræ of the *Cetiosaurus*, have been discovered in the Wealden formations, has induced me well to consider the grounds for assigning them to Saurians of distinct genera. But the general constancy of the vertebræ of the same Saurian in their antero-posterior diameter, forbids the supposition of a vertebra of six inches in length in the neck being associated with one of three inches in length in the back. Additional evidence of a very decisive character must at least be obtained before the great Cetiosaur can be admitted to have resembled the Pterodactyle in such disproportionate length of the cervical vertebræ.

The height of this dorsal vertebra to the posterior origin of the spinous process is 9½ inches: from the base of the neurapophysis to the upper part of the transverse process, measures 3 inches.

No. "$\frac{115}{2115}$" in the Mantellian Collection, ("Vertebra of *Iguanodon*, 8 inches in diameter," MS. Catalogue), may have actually presented that dimension when entire, for even now, not allowing for the margin of the posterior articular surface which has been broken away, it measures 7 inches across that surface. This remarkable specimen, which may probably have afforded the type of the 'third or plano-concave' vertebral system, in the summary of the vertebral characters of the Wealden reptiles given by Dr. Mantell in his 'Geology of the South-east of England*,' and which accords best with the characters assigned by M. H. von Meyer to the vertebræ of the *Iguanodon*†, presents, in fact, in a striking degree, those of the vertebræ of the *Cetiosaurus*, and belongs to a more posterior part of the dorsal region, perhaps to the loins, of the same individual, certainly to one of the same species, as the vertebra (No. 2133) last described.

The anterior articular extremity makes the same approach to a plane surface, being slightly concave below and very slightly convex above: the depth of the posterior concave surface at the centre is 9 lines. The general contour of the centrum has begun to change from the circular to the subquadrate, which latter figure is more decidedly expressed in the anterior caudal vertebræ of the *Cetiosaurus brevis*.

The upper half of the sides of the centrum are more concave in the axis of the vertebra than in No. 2133. The free surface presents the same degree of smoothness, and is pierced here and there by moderate-sized vascular foramina. The spinal canal makes a slight depression in the upper part of the centrum: in the *Iguanodon* it is encompassed by the bases of the neurapophyses. The transverse diameter of the spinal canal is 1 inch, which small dimension satisfactorily distinguishes the present enormous vertebra from those of the mammiferous class, viz. the Cetacea, to which in other respects it has the greatest similitude. The antero-posterior diameter of the base of the neurapophysis is 2 inches.

The four anterior caudal vertebræ in the Mantellian Collection, which are here assigned to the *Cetiosaurus brevis*, slightly increase in antero-posterior diameter, as is the case in the *Cetiosaurus medius*, as they recede from the trunk, which seems to indicate that the present gigantic marine Saurian must have had a capacious and bulky trunk, but propelled by a longer and more Crocodilian tail than in the modern whales. It is sufficiently evident, however, that, even in the present short segment of the tail, with the slight increase of length, there is a diminution of height and breadth of the centrum, and a still more obvious subsidence of the neural arch, as the vertebræ recede from the trunk. As compared with the dorsal vertebræ, the chief change of form is the subquadrate contour produced by a lateral extension and flattening of the lower surface of the centrum, which is more essentially distinguished by four hæmapophysial articular surfaces, two at the anterior and two at the posterior margins of this inferior surface. The articular surfaces at both ends of the centrum are now concave; and the anterior one, which was nearly flat in the dorsals, is here the deepest; it is one inch deep at the upper third of the surface*. The sides of the centrum at the upper half are concave both lengthwise and vertically, forming a wide depression below the transverse process; the middle part of the side begins to stand out and divide the upper from the lower lateral concavity, which character, being more strongly developed in the hinder caudal vertebræ, gives the rhomboidal or hexagonal form†. The lower half of the side of the centrum is less concave than in the dorsal vertebræ. The broad inferior surface is also less concave antero-posteriorly than in the dorsal vertebræ, and is nearly flat transversely: it gradually contracts, in the transverse direction, in the posterior caudals, so as to take on the form of a longitudinal sulcus. The two anterior hæmapophysial surfaces are separated from each other by an interval of two inches; the two posterior surfaces, which are larger than the anterior ones, are similarly distinct.

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* 8vo, 1833, p. 296, fig. 3.

† Palæologica, p. 212.

In the *Iguanodon* the hæmapophysial surfaces are confluent on both the anterior and posterior parts of the under surface of the centrum, and the chevron bones accordingly present modifications by which they may, when detached, be distinguished from those of the *Cetiosaurus*.

The transverse processes have descended, as usual, from the summit to the base of the neural arch in the present anterior caudal vertebræ. They are short, compressed vertically, diminishing, and as if slightly twisted, so that the upper margin is turned forwards, at their extremity. The vertical diameter of the base of the transverse process in the largest of the present caudal vertebræ is three inches; its anterior-posterior diameter one inch six lines; its length two inches seven lines: the extremity terminates obtusely. The upper ridge-like termination of the transverse process is continued to the base of the anterior oblique processes. These processes are alone developed in the present vertebræ, the posterior articular surfaces being impressed upon the sides of the posterior part of the base of the spine. The anterior oblique processes project almost horizontally forwards, diminishing, chiefly in vertical diameter, to an obtuse apex; convex externally, flattened internally by the oblong articular surface, and separated by a fissure nearly one inch wide: the length of these processes, from the bottom of the intervening fissure in the second of the four caudals, where they are most entire, is two inches. When the vertebræ are placed in juxtaposition, these processes reach beyond the middle of the vertebræ next in front, and pinch, as it were, the back part of the base of the spine so as to impress upon it the surfaces representing the posterior articular processes. These processes are well developed, on the contrary, in the corresponding vertebræ of the *Iguanodon*, and overhang the posterior surface of the body of the vertebra to which they belong. The spinous process, which appears to be nearly perfect in the second caudal, is short, strong, and truncated at the summit. Its height from the anterior oblique processes is four inches: the total height of the vertebra is thirteen inches. The antero-posterior diameter of the side of the neural arch is two inches. The spinal canal is wider in these caudal than in the dorsal vertebræ, indicating the greater muscularity of the part deriving its nervous power from the corresponding part of the spinal chord: its transverse diameter is one inch ten lines; its vertical diameter is two inches. The neural arch is, as usual in the present genus, anchylosed to the anterior part of the upper surface of the centrum: one inch and a half of this surface is left free behind the attachment of the arch. The finely wrinkled or fibrous character of the free surface is more strongly marked in these caudal than in the dorsal vertebræ.

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* The same modification of the articular extremities occurs in the caudal region of the vertebral column of the *Plesiosaurus*. See 'Report on Brit. Foss. Reptiles,' part i. Trans. Brit. Assoc. 1839, p. 58.

† It is one of these posterior caudals of the *Cetiosaurus*, which is figured as the type of the "second vertebral system" in the 'Geology of the South-east of England,' p. 296, fig. 2.

In the three succeeding vertebræ the neural arch diminishes in height, the anterior articular processes diminish in length, and the posterior articular impressions in depth. The upper and lower parts of the sides of the body become somewhat more concave; the posterior articular surface grows flatter.

A detached chevron bone, eight inches in length, consisting of two hæmapophyses, anchylosed only at their distal or inferior extremities, and with their distinct proximal ends more divaricated than are the confluent ones in the *Iguanodon*, corresponds with the caudal vertebræ here described, and doubtless belongs to the *Cetiosaurus brevis*.

The following are dimensions taken from the four caudal vertebræ above described:—

	1st.		2nd.		3rd.		4th.	
	In.	Lin.	In.	Lin.	In.	Lin.	In.	Lin.
Antero-posterior diameter of centrum .	3	9	4	2	4	3	4	3
Transverse diameter of centrum . .	7	2	7	1	6	9	6	4
Vertical diameter of centrum . . .	6	10	6	8	6	0	6	0

Of the present species of *Cetiosaurus*, I have examined specimens of the bodies of one dorsal and three posterior caudal vertebræ in the collection of Gilpin Gorst, Esq., which were obtained from the central strata of the Wealden, near Battle Abbey, commonly called the 'Hastings beds.'

The dorsal centrum closely agrees with those in the Mantellian Collection: its anterior surface is, as in them, nearly flat, or slightly convex; the posterior surface is concave.

	In.	Lines.
The antero-posterior diameter	3	2
The transverse diameter of the anterior surface . . .	5	3
The vertical diameter of the anterior surface	5	2

A fracture of this centrum through its middle shows it to consist throughout of a coarse cellular texture. The neurapophyses, with an antero-posterior extent of base of two inches three lines, are continuously anchylosed with the centrum, as in Mammalia, and leave about three quarters of an inch of the posterior part of the centrum free. The lower part of the spinal canal is horizontal; its transverse diameter one inch three lines.

The posterior caudal vertebræ present an antero-posterior diameter of nearly four inches, with a breadth of three and a half inches, and a depth of four inches, measuring to the lower part of the posterior hæmapophysial surface. The antero-posterior length of the base of the neurapophysis is two inches two lines; and it does not begin so close to the anterior part of the centrum as in the dorsal vertebra. The upper and lower portions of the side of the centrum are more distinctly separated by the comparative projection of the middle part, which gives the obscurely hexagonal form to these vertebræ. The inferior parts are most concave, and converge to form the sides of the longitudinal sulcus, to which the inferior surface of the centrum is reduced at this part of the tail. It is plain, from these modifications of the vertebræ, that the tail must here have presented the compressed Crocodilian type; and it is satisfactory to have these indications of the Saurian affinities of the present gigantic fossil, in consequence of the very close approximation of the larger vertebræ to the Cetaceous type. The vertical extent of the osseous basis of the tail was here augmented by strong hæmapophyses, which have left more prominent articular facets on the under part of the centrum than in the larger anterior caudal vertebræ: these facets, instead of being in pairs, are confluent at the anterior, and at the posterior ends of the lower surface; the posterior confluent pair, forming a triangular prominent surface, inclining obliquely forwards, and with its apex notched by the termination of the inferior sulcus.

There are several posterior caudal vertebræ of the *Cetiosaurus brevis* in the Mantellian Collection, which closely correspond with those just described from the Hastings beds; four of these vertebræ give the following dimensions:—

	Nos. 2112.		2142.		2153.			
	In.	Lin.	In.	Lin.	In.	Lin.	In.	Lin.
Antero-posterior diameter of centrum . .	4	3	3	10	3	7	3	0
Transverse diameter of its articular end .	3	10	3	0	2	8	1	4
Vertical diameter of its articular end . .	4	0	3	3	3	0	1	5
Vertical diameter at middle of the centrum	4	6	3	11	3	10	1	2

The vertebræ figured in the 'Illustrations of the Geology of Sussex,' pl. ix. fig. 8, and pl. x. fig. 1, are posterior caudal vertebræ of the *Cetiosaurus brevis*.

Cetiosaurus brachyurus.—A dorsal and a caudal vertebra from the Wealden formation at Tetham, which agree in essential characters with the *Cetiosaurus*, and differ from those of *Streptospondylus*, *Megalosaurus*, *Iguanodon*, *Hylæosaurus*, *Poikilopleuron*, and the Crocodilian vertebræ of the Wealden, offer at the same time proportions which forbid their reference to the *Cetiosauri brevis*, *medius* and *longus*, and indicate a species distinguished by a shorter tail.

The dorsal vertebra (No. $\frac{109}{2109}$, Mantellian Collection) presents a subcircular centrum, with the neurapophyses anchylosed, but broken off; they are shorter than the centrum, and leave eight lines of its hind part uncovered. The anterior articular surface of the body is slightly convex at the upper, and concave at the under half: the posterior surface is uniformly concave: the body is constricted at the middle, but in a less degree than in the *Cetiosaurus brevis*, so that it is less deeply concave lengthwise: it is as convex transversely: a slightly-raised obtuse ridge separates two shallow sulci at the under surface of the vertebra.

The caudal vertebra (No. $\frac{161}{2161}$, Mantellian Collection) presents a shallow and rather oblique sulcus along the lower surface. The hæmapophysial articulations are most marked at the posterior part of this surface. The sides of the centrum are less concave longitudinally than in the dorsal vertebra; there is a vascular perforation on each: the articular ends of the body agree with those of the dorsal vertebræ. The following are dimensions of the preceding vertebræ:—

	Dorsal.		Caudal.	
	In.	Lin.	In.	Lin.
Antero-posterior diameter of body . . .	3	0	2	9
Vertical diameter of articular end . . .	4	3	3	10
Transverse diameter of articular end . .	4	6	3	7

These vertebræ closely corresponded in texture and character of the external surface*.

Cetiosaurus medius.—The remains of this Reptile have hitherto been discovered only in the oolitic strata below the Wealden. They appear to have been first noticed in a letter from John Kingdon, Esq., read at the meeting of the Geological Society held June 3rd, 1825, in which "he mentions the situation in which certain bones of a very large size, appearing to have belonged to a whale and a crocodile, were lately found completely imbedded in the oolite quarries (lower oolite), about a mile from Chipping Norton, near Chapel House." It is principally on these bones, with others subsequently discovered and in the collection of Mr. Kingdon, that the characters of the *Cetiosaurus* were first determined*. They include a portion of the tail consisting of ten vertebræ; the anterior and larger ones were five inches and a half in length, seven inches across the articular surface at each end of the body, and not less than two feet in vertical diameter, including the neural (superior) and hæmal (inferior) spines. Both articular extremities are concave, the anterior one being rather the deepest; but the difference is less than in the *Cetiosaurus brevis*. The articular cavities become shallower in the posterior caudal vertebræ; these gradually diminish in transverse and vertical diameter, but retain the same length, even when they are reduced to two inches and one inch and a half in breadth. The body of the vertebra has no central cavity, in which respect the present, like the preceding species of *Cetiosaurus*, may be distinguished from the *Poikilopleuron*, where such cavity exists. The neurapophysis does not equal in antero-posterior extent the centrum or body of the vertebra, the disparity increasing in the posterior caudal vertebræ: the arch is placed towards the anterior end of the vertebra. The hæmapophysial arch has a less contracted base than in the *Iguanodon*, and the proximal extremities of the hæmapophyses are free, as in the *Cetiosaurus brevis*.

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* They are probably the bones alluded to in the Note at p. 221 of Dr. Mantell's 'Geology of the South-east of England.'

One of the ungual phalanges, which is conical, subcompressed, and slightly curved, is traversed on each side by the usual vascular groove, curved with the convexity upwards, measuring five inches in length, and three and a half across its articular base. The bone alluded to in Buckland's 'Bridgewater Treatise,' vol. i. p. 115, and figured in Mr. Lyell's 'Elements of Geology' (1838), p. 384, is a metatarsal of the *Cetiosaurus*. This fossil was found in the great oolite of Enstone, near Woodstock.

A few large caudal vertebræ, and other bones of the *Cetiosaurus*, have been discovered in the oolite of the neighbourhood of the town of Buckingham, and form part of Dr. Buckland's museum.

Some vertebræ, an entosternal bone, a coracoid, scapula, and fragments of long bones, belonging apparently to the same skeleton, were disinterred from the middle oolite during the railway cuttings near Blisworth, and are preserved in the collection of Miss Baker at Northampton. The anterior transverse branch of the entosternum measures upwards of four feet across. The posterior caudal vertebræ, which, like those from Chipping Norton, measure five inches and a half in length, have a more hexagonal form, resembling, in this respect, the terminal caudal vertebræ of the *Cetiosaurus brevis* of the Wealden; they are, however, like the Chipping Norton specimens, of greater length.

In the museum of Professor Sedgwick, there is a caudal vertebra of the *Cetiosaurus* from the neighbourhood of Stratford-on-Avon. The size of the fossils hitherto obtained of the *Cetiosaurus medius*, especially the vertebræ, if calculated according to the numbers and proportions of those of the Crocodiles, gives a length of forty feet to this species.

Cetiosaurus longus.—In Professor Buckland's museum are preserved some fossil remains, principally vertebræ, of another enormous Saurian, which the form and texture of the vertebræ prove to belong to the genus *Cetiosaurus*, but which differ in the proportions of the vertebræ. One of these —a caudal vertebra—from the Portland stone at Garsington, near Oxford, measures in antero-posterior diameter of the centrum seven inches; in transverse diameter, seven inches nine lines; in vertical diameter of the centrum, six inches. Both articular extremities of the vertebra are slightly concave; the body is slightly compressed laterally; its middle part gives a subquadrate vertical section, with the angles slightly rounded; the expanded articular ends are subcircular. A fractured dorsal or lumbar vertebra, from the same locality, with transverse processes extending obliquely backwards from the upper part of the sides of the body, measures one foot across the nearly flat articular surface. The body of a caudal vertebra of the same species, from the Portland stone at Thame, measures seven inches four lines in antero-posterior diameter; six inches six lines in transverse diameter; and seven inches eight lines in vertical diameter. The under surface is concave lengthwise, and nearly flat from side to side; it is perforated by many large vascular canals. A third caudal vertebra is somewhat shorter in antero-posterior diameter, but exceeds the preceding in vertical diameter, which is eight inches. In all these vertebræ the neurapophyses are anchylosed to the centrum, and have a smaller antero-posterior extent at their base than the centrum, as in the preceding species of *Cetiosaurus*. In all the species the hæmapophyses are articulated to the interspaces of two vertebræ. To the *Cetiosaurus longus* is referable a vertebra, eight inches in length of body, and nine inches in transverse diameter, from the Yorkshire oolite at White Nab, which, together with some metatarsal bones, are deposited in the museum at Scarborough. No teeth, or fragments of jaws or cranium, have hitherto been discovered, which can, with certainty, be referred to any of the preceding species.

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* See Proceedings of the Geological Society, June 1841.

The names which I propose to give to these species refer to the relative length of their vertebræ, and from what we know of the constancy and regularity of this dimension in the back bone of individuals of the same species of Saurian, these specific names would, if we had the entire animals, be found to be as appropriate in reference to the relative length of their whole bodies.

At present the *Cetiosaurus brevis* is known to me only by specimens from the Wealden strata; the *Cetiosaurus medius* by fossils from the lower oolite, and the *Cetiosaurus longus* by a few vertebræ from both the upper and the lower oolite; but how far these species should actually characterize these divisions of the great oolitic system, will depend on the results of ulterior researches and a longer experience. It is certain, however, that we have in these remains ample proof of the existence, at that period of the earth's history which has been aptly termed the 'Age of Reptiles,' of another gigantic genus in addition to the *Pliosaurus*, *Poikilopleuron*, *Streptospondylus*, *Iguanodon*, *Megalosaurus* and *Hylæosaurus*.

The enormous *Cetiosauri*, some of which must have rivalled the modern whales in bulk, may be presumed to have been of strictly aquatic and most probably of marine habits, on the evidence of the sub-biconcave structure of the vertebræ, and of the coarse cancellous tissue of the long bones, which show no trace of medullary cavity. In the great expanse of the coracoid and pubic bones, as compared with the Teleosaurs and Crocodiles, the gigantic Saurians in question manifested their closer affinity to the *Enaliosauria*: their essential adherence to the Crocodilian type is marked by the form of the long bones of the extremities, especially the metatarsals; and, above all, by the toes being terminated by strong claws. The main organ of swimming is shown, by the strength and texture, and vertical compression of the posterior caudal vertebræ, to have been a broad vertical tail: and the webbed feet, probably, were used only partially in regulating the course of the swimmer, as in the puny Amblyrhynchus of the Gallipagos Islands, the sole known example of a Saurian of marine habits at the present period.

DINOSAURIANS.

This group, which includes at least three well-established genera of Saurians, is characterized by a large sacrum composed of five anchylosed vertebræ of unusual construction, by the height and breadth and outward sculpturing of the neural arch of the dorsal vertebræ, by the twofold articulation of the ribs to the vertebræ, viz. at the anterior part of the spine by a head and tubercle, and along the rest of the trunk by a tubercle attached to the transverse process only; by broad and sometimes complicated coracoids and long and slender clavicles, whereby Crocodilian characters of the vertebral column are combined with a Lacertian type of the pectoral arch; the dental organs also exhibit the same transitional or annectent characters in a greater or less degree. The bones of the extremities are of large proportional size, for Saurians; they are provided with large medullary cavities, and with well developed and unusual processes, and are terminated by metacarpal, metatarsal and phalangeal bones, which, with the exception of the ungual phalanges, more or less resemble those of the heavy pachydermal Mammals, and attest, with the hollow long-bones, the terrestrial habits of the species.

The combination of such characters, some, as the sacral ones, altogether peculiar among Reptiles, others borrowed, as it were, from groups now distinct from each other, and all manifested by creatures far surpassing in size the largest of existing reptiles, will, it is presumed, be deemed sufficient ground for establishing a distinct tribe or sub-order of Saurian Reptiles, for which I would propose the name of *Dinosauria* *.

Of this tribe the principal and best established genera are the *Megalosaurus*, the *Hylæosaurus*, and the *Iguanodon*; the gigantic Crocodile-lizards of the dry land, the peculiarities of the osteological structure of which distinguish them as clearly from the modern terrestrial and amphibious *Sauria*, as the opposite modifications for an aquatic life characterize the extinct *Enaliosauria*, or Marine Lizards.

MEGALOSAURUS.

Of the gigantic Lacertians in question, the most remarkable are the *Megalosaurus*, *Iguanodon*, and *Hylæosaurus*, the worthy fruits of the laborious researches of Prof. Buckland and Dr. Mantell. With respect to the *Megalosaurus*, the great carnivorous terrestrial Lizard of the Wealden and Oolitic period, the lucid descriptions of its discoverer in his original Memoir and the 'Bridgewater Treatise,' and the judicious remarks of Cuvier on its natural affinities, leave little to be added, save the observations on the sacrum, to the present brief record of the strata and localities in which the remains of the *Megalosaurus* have been found.

The most complete collection of the bones of this genus has been derived from the oolite of Stonesfield, where the original specimens were first discovered. Dr. Buckland now possesses in his valuable collection portions of a lower jaw, the principal fragment containing a tooth fully developed, and the germs of several others; detached dorsal, caudal, and a series of five sacral vertebræ, ribs, two coracoid bones, a clavicle, humerus, radius, an ilium, an ischium, a femur, fibula, metacarpal and metatarsal bones.

These parts have not been discovered so associated together as to prove them to belong to the same animal; but the peculiar characters of some of the bones, which distinguish them from the other oviparous reptiles of the same strata, and the agreement in texture and proportionate size of the others, render their reference to the *Megalosaurus* highly probable.

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* Gr. δεινὸς, fearfully great; σαύρος, a lizard. In the tabular arrangement of extinct Saurians founded by M. Herm. v. Meyer on the development of their organs of motion, the *Megalosaurus* and *Iguanodon* are grouped together in Section B, with the following character:—Saurians with locomotive extremities like those of the bulky terrestrial Mammals: "(Saurier mit Gliedmassen ähnlich denen der schweren Landsaügethiere)."—Palæologica, p. 201. No other grounds are assigned for their separation from other Saurians.

The essential characters of the most authentic of these remains prove the *Megalosaurus* to have been closely related to the Lacertian division of the Saurian order; but the teeth, the vertebræ, and some of the bones of the extremities, indicate its affinities to the Crocodilian group, and all these parts manifest more or less strongly the peculiar characters of its own remarkable family. In the instructive and characteristic portion of the lower jaw, the sockets, like the teeth, are compressed, and are separated by complete partitions; but they are so much wider than the teeth, as to suggest the existence of a greater proportion of ligamentous gum at the upper part of the alveolar tract in the recent animal than in the Crocodiles. "The outer rim of the jaw rises almost an inch above the inner rim, and forms a continuous lateral parapet, supporting the teeth externally; whilst the inner rim throws up a series of triangular plates of bone, forming a zigzag buttress along the interior of the alveoli. From the centre of each triangular plate, a bony septum crosses to the outer parapet, thus completing the alveolus*." There is a slight groove and ridge along the inner side of the sockets, and it is at this groove, at the interspace of each triangular plate, that the apices of the new teeth protrude. The teeth have compressed, conical, pointed crowns, with trenchant and serrate anterior and posterior edges. They appear straight when they first protrude, but are bent in the progress of growth; in the course of development the crown of the tooth is solidified, and the anterior margin at the base of the crown becomes smooth and convex. The smooth enamelled surface of the tooth presents fine polished wrinkles.

In all existing Lizards the teeth are anchylosed, either to the side of an outer alveolar parapet, according to the pleurodont type, or to its summit, according to the acrodont type. The double parapet, inclosing and concealing the germs and the bases of the full-grown teeth, is a remarkable approach in the present gigantic Dinosaur to the Crocodilian structure, the similarity in this respect no doubt resulting from a similar necessity in the carnivorous Megalosaur for a firm lodgment of the destructive maxillary weapons. The higher development of the outer alveolar parapet bespeaks the affinity of the *Megalosaurus* to the Lizards: in the form of the teeth it approaches nearest to the Varanian family, which at the present day includes the largest, and most carnivorous species of Lizard.

Vertebræ.—The Megalosaur deviates more decidedly from the existing Monitors and Lizards in its vertebral characters. These are afforded, at present, by the sacral, a few costal and caudal vertebræ. The articulating surfaces of the body of the vertebra are nearly flat or slightly concave, as in the cœlospondylian† Crocodiles. The non-articular surface is remarkably smooth and polished. The body is much contracted in the middle: the margins of the expanded articular extremities are thick and rounded off. The middle contracted part of the body is nearly cylindrical, being nipped in, as it were, by a more or less deep longitudinal fossa on each side, just below the base of the neural arch, but again slightly expands to support that part. The length of the base of the neurapophysis is nearly equal to that of the centrum: the suture is persistent, as in Crocodiles; its course is undulating, and it rises in the middle. The neurapophysis ascends and inclines outwards, to form, at a height above the centrum equal to three-fourths its vertical diameter, the margin of a broad platform of bone, from the sides of which the transverse processes are developed, and from the middle part the spinous process. A strong ridge or buttress of bone extends from the posterior angle of the base of the neurapophysis obliquely forwards to the under part of the transverse process; behind which ridge there is a deep depression, separating it from the posterior articular process. These processes are relatively smaller than in the *Iguanodon*, and do not project beyond the hinder end of the centrum. The spinal platform descends in a gentle curve from the posterior to the anterior oblique processes: the base of the strong and thick spinous process follows this curve along the middle line of the platform; its antero-posterior extent was 4½ inches, in a vertebra having the centrum of the same length, with a vertical diameter of 4 inches, and measuring 7½ inches from the under part of the centrum to the posterior part of the base of the spine.

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* Transactions of the Geological Society, 2nd Series, vol. i. p. 395.

† I find this collective term convenient in application to those Crocodilians which have the vertebræ concave at both ends.

Sacrum.—The sacrum of the *Megalosaurus* consists of five anchylosed vertebræ, and it is remarkable enough, considering how small a proportion of the recognizable bones of this rare reptile has been found, that the present characteristic part of the vertebral column of three different individuals should have been obtained: one sacrum, from Stonesfield, is in the museum of Dr. Buckland at Oxford; a second sacrum, from Dry Sandford, in the museum of the Geological Society; and a third sacrum, from the Wealden formation, in the British Museum.

I have studied each of these specimens with much attention, which a recognition of their remarkable structure has well repaid.

It would seem that Cuvier did not regard the five anchylosed vertebræ figured in Dr. Buckland's original memoir, as the sacrum of the *Megalosaurus*. They are briefly alluded to in the second and fourth editions of the 'Ossemens Fossiles,' and in the description of the Plate, in which Dr. Buckland's figure is reproduced as a 'Suite de cinq vertèbres de *Mégalosaurus*.' In truth the sacrum was not known to be represented, at that time, in any Saurian by more than two vertebræ, and therefore Dr. Buckland mentions this part in his original memoir as "five anchylosed joints of the vertebral column, including the two sacral and two others, which are probably referable to the lumbar and caudal vertebræ *." In contemplating this series of five anchylosed vertebræ, so new in Saurian anatomy, my attention was first arrested by the singular position of the foramina for the transmission of the nerves from the inclosed spinal marrow. These holes, which, in the plate illustrating Dr. Buckland's important memoir † are represented above the bodies of the three middle vertebræ, are natural, and accurately given: the smooth external surface of the side of the vertebra may be traced continuing uninterruptedly through these foramina, over the middle or nearly the middle of the centrum, into the surface of the spinal canal.

But the normal position of these foramina throughout the vertebral column in all other reptiles is at the interspace of two vertebræ, whence by French anatomists these holes are termed 'trous du conjugaison.' In the sacrum of the Oxford Megalosaur, however, it is evident that above the anchylosed intervertebral space a thick and strong imperforate mass of bone ascends to the base of the spinous process, leaving it to be conjectured either that the nerve had perforated the middle of the neurapophysis, or that these vertebral elements had undergone in this region of the spine a change in their usual relative position to the centrum. Previous researches into the composition and modifications of the vertebræ in the different classes of Vertebrata soon enabled me to recognize the peculiar condition and analogies of the five anchylosed vertebræ of the *Megalosaurus*; with a view to illustrate which I shall premise a few observations on the different relative positions which the peripheral vertebral elements may take in regard to the central part or body. The lateral vertebral elements, or ribs, the inferior laminæ or hæmapophyses, the superior laminæ or neurapophyses, are all subject to such changes; but the neurapophyses are much more constant in their place of attachment than the others. In Mammalia the ribs for the most part are joined to the interspace of two centrums; in Reptiles each pair is attached to a single centrum. In Fishes, and the Mosasaur among Reptiles, the hæmapophyses depend, each pair from its proper centrum; in other Reptiles and Mammalia they are articulated to the interspace of two vertebræ, leaving a half-impression on each of the contiguous centrums. The neurapophyses present a degree of constancy in their relation to the body of the vertebra corresponding with the importance of their function. In Mammalia I know of no exception to the rule, that each neural arch is supported by a single centrum: in Birds no exception has hitherto been recorded; but among Reptiles the Cheloniæ* offer in those vertebræ, in which the expanded spinous processes contribute to form the carapace, the interesting modification analogous to those noticed in the lateral and inferior vertebral elements, viz. a shifting of the superior laminæ from the middle of the body to the interspace of two adjoining centrums; whereby that part of the spine subject to greatest pressure is more securely locked together, and a slight yielding or elastic property is superadded to the support of the neural arch.

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* Geol. Trans., 2nd Series, vol. i. p. 395, pl. xlii. fig. 1.

† Ibid.

The same modification is introduced into the long sacrum of birds; each neural arch is there supported by two contiguous vertebræ, the interspace of which is opposite the middle of the base of the arch above, and the nervous foramen is opposite the middle of each centrum. It is this structure, beautifully exemplified in the sacrum of the young Ostrich, which Creative Wisdom adopted to give due strength to the corresponding region of the spine of a gigantic Saurian species, whose mission in this planet had ended probably before that of the Ostrich had begun.

The anchylosed bodies of the sacral vertebræ of the Megalosaur retain the distinguishing characters which have been recognized in the dorsal and caudal vertebræ, in regard to the smooth and polished surface of their middle constricted part; the cylindrical, or nearly cylindrical transverse contour of this part below the lateral depression; their expanded, thickened and rounded articular margins, and also, though in a somewhat less degree, their relative length as compared with their breadth and height. The three middle sacrals are, however, somewhat shorter than the two terminal ones.

	In.	Lin.
Antero-posterior diameter of centrum of fifth sacral . . .	4	10
Vertical diameter of centrum of fifth sacral	4	1
Transverse diameter of centrum of fifth sacral	4	6
Vertical diameter of the middle of the body	2	6
Total height of fourth sacral vertebra	11	

The neural arches of the first three sacral vertebræ rest directly over the interspaces of the subjacent bodies; that of the fourth derives a greater proportion of its support from its proper centrum; and that of the fifth, which rests by its anterior extremity on a small proportion of the fourth centrum, is extended over nearly the whole length of its own centrum, so that in the caudal vertebræ the ordinary relations of the neural arch and centrum are again resumed. In the four first sacral vertebræ the base of the neural arch extends half way down the interspace of the bodies, and immediately developes from its outer part a strong and short transverse process (broken and rounded off in the fossil). From the base of this process the neurapophysis expands upward, forward and backward, is joined by vertical suture to similar expansions of the contiguous neurapophysis, and terminates above in a ridge of bone, at right angles to the suture; this ridge, with those of the other neurapophyses, extends longitudinally above the transverse processes the whole length of the sacrum, and forms the margin of the platform from which the spinous and accessory processes are developed. The platform is further supported by a compressed ridge of bone extended from the upper part of the transverse process, like a buttress, to the middle of the horizontal ridge. On each side of the buttress there is a depression, which is deepest in front. The spinous process is not developed, as in the dorsal vertebræ, immediately from the platform, but a shorter, vertical plate of bone, of nearly the same longitudinal extent as the true spine, is developed on each side of, and parallel with its base; the height of these accessory spines in the third sacral vertebra is three and a half inches. The true spinous process begins to expand longitudinally, and when near the summit of the accessory spines, is joined by vertical suture with the similarly expanded neighbouring spines, so that the sacrum is crowned by a strong continuous vertical longitudinal ridge of bone, at least along the four first vertebræ; the broad spine of the fifth being rounded off anteriorly, and separated by a narrow interspace from that of the fourth. Besides this modification of the spine, and the more normal position of the neural arch of the fifth anchylosed vertebra, the origin of the transverse process has been suddenly raised to the level of the spinal platform, and it is supported by two converging ridges of bone from the side of the neural arch below. The origin of the transverse processes of the first sacral is also placed higher than the three middle ones, in which the several peculiarities of structure above described are most strongly marked.

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* Cuvier describes the exceptional structure above alluded to in these Reptiles, and likewise cites the Chondropterygians; 'Leçons d'Anat. Comparée,' ed. 1836, tom. i. p. 213.

The specimens of sacrum of the *Megalosaurus* in the British Museum, and that of the Geological Society, present the same structure as that above described in the original specimen at Oxford. Part of the fifth sacral vertebra is wanting in the specimen from Dry Sandford. The rest are characterised by the same smooth and polished surface, rich brown colour, contraction of the middle of the body, its cylindrical form transversely, and the longitudinal fossa below the annular part. The length of this series is one foot six and a half inches; the second and third sacral vertebræ are rather shorter than the rest. The first sacral vertebra, which was not anchylosed to the last lumbar, gives the following dimensions:—

	In.	Lin.
Antero-posterior diameter of centrum	5	0
Vertical diameter of anterior articular end	4	0
Transverse diameter of anterior articular end . . .	4	6

The neural arch seems not to have been co-extensive in length with the centrum, but rests on its anterior three-fourths. A strong and short transverse process extends obliquely upwards and backwards from each side of the arch; the antero-posterior diameter of the base of this process is two inches, its vertical diameter one and a half inch. In the second sacral vertebra the neural arch has moved forward upon the interspace between the first and second sacral bodies, and developes from a lower part of its base a stronger, thicker and longer transverse process, directed outwards and forwards. The third neural arch has its base transferred directly over the interspace of the second and third centrums; the diameters of the base of its transverse processes are three inches and two and a half inches: they incline slightly backwards. The fourth neural arch descends lower down upon the interspace between the third and fourth centrums. The fifth neural arch, as in the Oxford specimen, extends a little way across the interspace between the fourth and fifth centrums, but nearly resumes its ordinary place. The second and third sacral vertebræ are not so regularly convex below in the transverse direction, but their sides converge so as to give a slight indication of a broad obtuse ridge. The diameter of the spinal canal in the first and last sacral vertebræ is one inch.

The five vertebræ are not anchylosed in a straight line, but describe a gentle curve, with the concavity downwards; the series of transverse processes or sacral ribs, forms a curved line in the opposite direction, in consequence of their different positions. The summits of the anchylosed spines being truncated, describe a curve almost parallel with that of the under part of the vertebræ. The contour of the hinder part of the body of the present gigantic carnivorous lizard, doubtless raised high above the ground upon the long and strong hind-legs, must have been different from that of any existing Saurians. In these the relatively shorter hind-legs, being directed more or less obliquely outwards, do not raise the under surface of the abdomen from the ground; it is the greater share in the support of the trunk assigned to the hind-legs in the Megalosaur which made it requisite that, as in land mammals, a greater proportion of the spine should be anchylosed to transfer the superincumbent weight through the medium of the iliac bones upon the femora.

The femur, like the teeth and vertebræ, exhibits a mixture of the characters of the Monitor and the Crocodile. It is arched in two directions, being at first concave in front, and then behind. Its articular head is directed forwards, and has behind it a compressed and rather salient trochanter; it thickens towards the distal end, and there terminates in two unequal condyles. Near its upper third it has an expansion on both the inner and the outer side, like the one which is seen on the internal side of the femur in the Crocodile. The femur of the Monitor is less arched. The medullary canal is wide, which removes the Megalosaur from the Crocodiles, and indicates, as Dr. Buckland has well shown, its aptitude for a more terrestrial life.

The ribs, which from their colour, texture, and proximity of deposit, belong most probably to the *Megalosaurus*, present a double articulation with the vertebral column; the head is supported on a long and strong compressed neck, thickest at its under part; the tuberosity is large. One of the small cervical false ribs is preserved, the free extremity of which gradually tapers to a point.

The scapula is a thin, slightly-bent plate, of equal breadth, except where it is expanded and thickened towards the humeral end, but thinning off again towards the articular margin. The chief support of the humerus seems to have been afforded by a large and broad coracoid. The antero-posterior diameter of one of these bones, taken across the median, thin, slightly convex margin, is two feet three inches. The thickened process for the articulation with the scapula has a deep and narrow notch in front, and the deep and wide glenoid cavity for the humerus behind it; the posterior boundary of this cavity projects outwards in the form of an obtuse process. A short but strong process projects from the anterior part of the coracoid analogous to that which in the Varanian Monitors and most other Lizards abuts against the epicoracoids, and which bespeaks the existence of the epicoracoids in the *Megalosaurus*. The characteristic coracoid bone illustrates most unequivocally the affinities of the *Megalosaurus* to the Lacertian group of reptiles; but compared with the coracoid of a Varanian Monitor, four feet nine inches in length, it is sixteen times as large. This magnitude in a reptile, Cuvier justly observes, is quite appalling; for, other proportions being the same, the *Megalosaurus* must have exceeded seventy feet in length.

A long and slender bone, nearly two feet in length, most resembles the clavicle of certain lizards, especially, as Cuvier remarks, those of the great

Scincus. It is slightly arcuated longitudinally, subtrihedral in the middle, flattened and expanded at the two extremities. If it be really a clavicle, it forms as characteristic an indication of the Lacertian affinities of the *Megalosaurus* as the coracoid. According to the proportions of the clavicle in existing lizards, Cuvier observes that it bespeaks an animal nearly sixty feet in length.

A subcompressed, three-sided bone, flattened and slightly expanded at one end, thickened and more suddenly extended transversely at the opposite end, which formed part of a large cotyloid cavity, is most likely an ischium; its length is 18 inches; its breadth, at the middle of the shaft, 5 inches; at its articular end 9 inches, the thickness of this end being 4 inches. The ascending shaft of this bone is slightly twisted, convex and smooth on the outer side, flat and rough on the inner side.

Other bones, not improbably belonging to the *Megalosaurus*, are preserved in the British and Oxford Museums, and in the private collections of Messrs. Holmes and Saull; but further evidence of their Megalosaurian character must be obtained before a description of them can be profitably applied to the reconstruction of the skeleton of the present carnivorous Dinosaur.

A few words, however, may be added, touching the size of the *Megalosaurus*; for it appears to me that the calculations which assign to it a length of 60 and 70 feet are affected by the fallacy of concluding that the locomotive extremities bore the same proportion to, and share in the support of, the body, as they do in the small modern land lizards.

The most probable approximation to a true notion of the actual length of the *Megalosaurus*, is that which may be obtained by taking the length of the vertebræ as the basis. The antero-posterior dimension is the most constant which the vertebræ present throughout the spine: in most Crocodilian and Lacertian reptiles the cervical vertebræ are a little shorter than the dorsal; but these are of equal length, and the caudal vertebræ maintain the same length to very near the extremity of the tail.

As the dorsal vertebræ of the *Megalosaurus* agree, in the important character of the mode of articulation of the ribs, with the Crocodiles, it may be regarded as most probable that they also corresponded in their number. This does not exceed 14 in recent Crocodiles, nor 16 in any of the known extinct species; taking, then, the latter number, and adding to it 7, the usual number of the cervical vertebræ in Crocodiles, we may allow the *Megalosaurus* 23 vertebræ of the trunk.

The length of the body of a large dorsal vertebra of the *Megalosaurus* in the British Museum is 4½ inches: from the analogy of the *Iguanodon*, in which several dorsal vertebræ have been discovered in their natural juxtaposition, it is probable that the thickness of the intervertebral substance did not exceed one-third of an inch: but if we multiply 23 by 5, not allowing for the probable shortness of the cervical vertebræ, we only then attain a length of 9 feet 7 inches. If, however, setting aside the analogy of the *Megalosaurus* to the Crocodiles in the structure of the vertebræ, we take that species of Lacertian which it most resembles in the structure of the teeth, and found our calculation on the number of vertebræ of the trunk in such lizard, then, the great carnivorous Varanian Monitor of Java having 27 vertebræ of the trunk, we do not, even calculating the same number of vertebræ to have occupied each a space of five inches in the *Megalosaurus*, obtain a length of trunk exceeding 11 feet 3 inches.

I should consider the first calculation, or about 10 feet, to have been the most probable natural length.

To this we must add 1 foot 10 inches for the known length of the sacrum. Thus 12 feet will be a fair or even a liberal allowance of length from the occiput to the beginning of the tail. In Crocodiles the skull equals about 12 dorsal vertebræ in length. In the Java Monitor the proportion of the head is less. In the Iguana the cranium does not exceed 6 dorsal vertebræ in length.

We may consider therefore 5 feet, taking the Crocodile as the term of comparison, as probably not below the length of the head of the Megalosaur. With regard to the tail, this includes between 36 and 38 vertebræ in Crocodilians, but varies from 30 to 115 in the small existing Lacertians, in many of which it is a prehensile organ, aiding them in climbing and other actions suitable to their size. It is very improbable that the tail should have presented such unusual proportions in the great Saurian under consideration, and indeed very few caudal vertebræ of the Megalosaur have been as yet discovered, and none exceeding 4 inches in length. Allowing the Megalosaur to have had the same number of vertebræ as the Crocodile, and multiplying this number 36 by 4½, a length of 12 feet 6 inches is thus obtained for the tail. A calculation on this basis thus gives, in round numbers,

Length of head	5	feet.
Length of trunk, with sacrum	12	—
Length of tail	13	—
Total length of the *Megalosaurus*	30	—

Upon this mode of obtaining an idea of the bulk of the present extinct reptile I am disposed to place the greatest reliance, and conceive that any error in it is more likely to be on the side of exaggeration than of curtailment. From the size and form of the ribs it is evident that the trunk was broader and deeper in proportion than in modern Saurians, and it was doubtless raised from the ground upon extremities proportionally larger and especially longer, so that the general aspect of the living Megalosaur must have proportionally resembled that of the large terrestrial quadrupeds of the Mammalian class which now tread the earth, and the place of which seems to have been supplied in the oolitic ages by the great reptiles of the extinct Dinosaurian order.

Besides the Stonesfield slate, the remains of the *Megalosaurus* have been found in the Bath oolite immediately below that slate, and in the cornbrash above it. The other formation in which the remains of the Megalosaur occur, next in importance to the Stonesfield slate, is the Wealden strata. Dr. Mantell has discovered in the ferruginous clay of the Forest of Tilgate a fine vertebra, and a portion of the femur of the *Megalosaurus*, 22 inches in circumference. Many teeth have been discovered altogether of the same form as those found by Dr. Buckland. Some fragments of the metacarpus and metatarsus from this locality, were thicker than those of a large hippopotamus. Mr. Holmes, surgeon at Horsham, possesses a good caudal vertebra, and some other parts of the *Megalosaurus* from the ferruginous sand near Cuckfield in Sussex. Remains of the *Megalosaurus* occur in the Purbeck limestone at Swanage Bay. In some of the private collections in the town of Malton, Yorkshire, are teeth, unquestionably belonging to the same species as the Stonesfield *Megalosaurus*, from the oolite in the neighbourhood of that town.

The tooth from the New Red Sandstone of Warwick figured in the Memoir by Messrs. Murchison and Strickland*, and referred to the *Megalosaurus*, belongs to another genus of Lacertian, more nearly allied to the *Palæosaurus* of the Bristol conglomerate.

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* Geol. Trans., 2nd Series, vol. v. pl. xxix. fig. 7.

HYLÆOSAURUS.

A second well-marked genus of Dinosaurian Reptiles is founded upon a large portion of the skeleton of the reptile to which the name at the head of this section has been applied by its discoverer, Dr. Mantell.

In assigning to this genus its present place in the Dinosaurian order, I have been guided by the structure of the vertebral column, especially the sacrum, and by the following considerations. The distinct alveoli in the jaws of the *Megalosaurus*, and the resemblance of its teeth to those of two extinct Crocodilians, viz. the Argenton species and the *Suchosaurus*, seemed to claim for that great carnivorous Dinosaur the next place to the Crocodilian order, among which the *Streptospondylus*, as has been shown, seemed to make the closest approximation to the *Megalosaurus*, in the great height, complexity and strength of the neural arch of the vertebræ. In the present genus, which there is good reason for believing to have resembled the Lizards more than the Crocodiles in its dental characters, an affinity to the Loricate Sauria is manifested not only by the structure of the vertebræ and ribs common to it with other Dinosaurs, but likewise by the presence of dermal bones, or scutes, with which the external surface was studded.

The *Hylæosaurus* has not been made known like the *Megalosaurus*, from detached parts of the skeleton successively discovered and analogically recomposed, but was at once brought into the domain of Palæontology by the discovery of the following parts of the skeleton in almost natural juxtaposition: viz. the anterior part of the trunk, including ten of the anterior vertebræ in succession, supporting a small fragment of the base of the skull; the two coracoids, the coracoid extremities of both scapulæ, detached vertebræ, several ribs more or less complete, and some remarkable parts of the dermal skeleton, including, apparently, enormous vertical plates or spines, arranged, as is supposed, in the form of a median dorsal ridge or crest of singular dimensions.

In the fragment of the cranium may be distinguished the pterygoid elements of the sphenoid bone, the inner margins of which touch anteriorly and then recede as they pass backwards, leaving a heart-shaped posterior nasal aperture, the apex of which is turned forwards. The breadth of this aperture is 1 inch 3 lines: its posterior position gives another character, by which the present Dinosaur, and probably the larger genera of the same order, resembled the Crocodiles more than the Lizards.

The bodies of the vertebræ are shorter in proportion to their breadth than in the *Megalosaurus* or *Iguanodon*. They have not so smooth and polished a surface as in the *Megalosaurus*, nor are they so contracted in the middle, or so regularly rounded below from side to side; a few of the anterior vertebræ are somewhat flattened below, so as to present an obscurely quadrate figure; most of the anterior dorsals are more compressed and keel-shaped below: the sacral and caudal vertebræ are longitudinally sulcated at their under surface.

The structure of the atlas and axis cannot be discerned in the Mantellian specimen; the second (conspicuous) cervical vertebra has its sides subcompressed, its under surface flattened, and the anterior part of the slight angular ridges separating it from the concave lateral surfaces, are produced anteriorly into two feebly-marked tubercles. The inferior transverse processes are developed from each side of the anterior part of the body of the vertebra; they are subcircular, very slightly prominent, about 7 lines in diameter.

In the fourth (conspicuous) vertebra, a large proportion, but not the whole, of a costigerous transverse process is developed from each side of the anterior part of the body, with the costal surface directed obliquely outwards and forwards. There is a small costal surface at the side of the expanded posterior extremity of the same vertebra, against which a part of the head of the fourth rib abuts; that and three of the succeeding ribs having their heads applied over the interspace of two contiguous vertebræ, as nearly throughout the thoracic region in Mammalia. The lateral compression of the centrum increases in the sixth and seventh (conspicuous) vertebræ, in which the under surface forms an obtuse ridge; in the eighth vertebra this surface is broader. In none of these vertebræ is a process developed from the under surface as in the hinder cervical and anterior dorsal vertebræ of the Crocodiles.

The most striking character of the vertebræ of the *Hylæosaurus* is the great development of the neural arch and its processes. The anterior articular processes extend (in the anterior dorsal and cervical vertebræ) over half the centrum next in front, and a broad upper transverse process is developed from the side of the neurapophysis and along its anterior continuation: this transverse process extends horizontally outwards, is notched anteriorly, and contracts to an obtuse point against which the tubercle of the rib articulates: the transverse processes are flat transversely, slightly concave lengthwise, and smooth below: they increase in length and strength as the vertebræ extend along the trunk; and the ribs, which they contribute to support, exhibit a still more rapid increase: the ribs present, as in the other Dinosaurs and Crocodiles, a bifurcated vertebral end for the double articulation above described*. The neck and head of the rib corresponding with the seventh conspicuous vertebra is 2 inches 2 lines in length; the tubercle, or upper head, is 10 lines long; the breadth of the rib at the point of bifurcation is 1 inch 1 line. The neck of the eighth rib has the same length as that of the seventh, but is twice as thick and strong; the tubercle is broader but shorter. Beyond the tubercle the shaft of the rib is bent at right angles with the neck. This soon begins to shorten, and the shaft of the rib to lengthen, until it becomes attached solely to the transverse process.

In the dorsal vertebræ the body increases in all its proportions, excepting its length. The lateral compression now manifests itself at the upper part of the centrum just below the neurapophysial suture; the under surface of the posterior dorsal and lumbar vertebræ is convex transversely, but in a less degree than in the *Megalosaurus*, and in some, it is obscurely carinated. The external surface at the middle contracted part of the vertebra is moderately smooth, but the minute striæ give it a somewhat silky lustre; it is longitudinally but irregularly ridged and grooved near the articular ends. These are both slightly concave at the centre, more slightly convex near the circumference. The difference between the vertebræ of the Hylæosaur and the biconcave Crocodilian vertebræ is chiefly manifested in the development of the neural arch. The modification of this part in the cervical vertebræ has already been mentioned. In the dorsal vertebræ each neurapophysis rises vertically, contracting in the axis of the vertebra, expanding transversely or outwardly, until it has attained a height equal to that of the centrum; there it expands into a broad and flat platform, from the middle line of which the broad spine is developed. A vertically compressed but strong transverse process is developed from the side of the neurapophysis, and is supported by a pyramidal underprop, extending upwards and outwards from the anchylosed base of the neurapophysis. There is a large, deep and smooth depression on each side of the base of the transverse process. The anterior surface of the neural arch, above the anterior oblique processes, is traversed by a vertical ridge, on each side of which there is a shallow depression*. The spinous process is of unusual thickness, its transverse breadth at the base measures 1 inch: this modification may probably relate to the support of great dermal spines. The spinal canal in the dorsal vertebræ is cylindrical, and expanded at both extremities; its diameter at the middle is 7 lines, at the expanded outlets 10 lines, in a posterior dorsal or lumbar vertebra. Here the bases of the neurapophyses begin to shorten, and leave a small proportion of the upper surface of the centrum uncovered at both ends, chiefly at the posterior end.

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* Dr. Mantell, in his Memoir on the Tilgate Saurians, Philos. Transactions, Part ii. for 1841, which I received while this Report was going through the press, says that "the bilobed head and the great external expansion of the arch of the rib in all probability bears a relation to the enormous development of the dermal spines," p. 143. But this is precisely the modification of the skeleton in which the *Hylæosaurus* differs most from the existing Saurians which possess such spines, as the *Cyclura*, and in which it most resembles the *Iguanodon* and *Megalosaurus*.

The following are dimensions taken from three of the vertebræ of the *Hylæosaurus*:—

	Second conspicuous cervical.		Fourth conspicuous cervical.		Middle dorsal.	
	In.	Lin.	In.	Lin.	In.	Lin.
Antero-posterior diameter of body .	1	10	2	2	2	9
Vertical diameter of its articular end	0	0	1	6	2	6
Transverse diameter of its articular end	2	0	2	2	3	0
Transverse diameter of middle of body	0	0	0	0	2	0

The differences between the vertebræ of the *Hylæosaurus* and *Megalosaurus* have been already pointed out, and are further shown in the admeasurements given above: the vertebræ of the *Hylævsaurus* differ from those of the *Iguanodon* in their greater transverse diameter, and in the breadth of their under part; those of the *Iguanodon* are flatter vertically along their whole sides, which converge to a narrower ridge at the under part. The vertebræ of the *Hylæosaurus* differ from those of the *Streptospondylus* in the sub-biconcave character of the articular ends of the centrum, and in its comparative shortness and thickness: the separated neural arch might be distinguished from that of the *Streptospondylus* by the simplicity of the supporting buttress of the transverse process; and, although equal in height, yet it is superior in the expansion and strength of the platform and spinous process.

Sacrum.—There is a portion of a sacrum of a small or young Dinosaur (No. $\frac{484}{2484}$, Mantellian Collection), which, in the form and proportions of the bodies of the vertebræ, most resembles the present genus, and cannot be referred to *Megalosaurus* or *Iguanodon*. It includes two entire and parts of two other vertebral bodies, anchylosed together, and to the bases of the neurapophyses; which, as in the *Megalosaurus*, are transferred to the upper and lateral parts of the interspaces of the subjacent bodies. These are moderately, but regularly, contracted in the middle and chiefly laterally, being more flattened below, where likewise each is traversed by a longitudinal sulcus. At the middle of each lateral concavity there is a vascular perforation. I am uncertain which is the anterior part of this interesting series; but, by the analogy of the *Megalosaurus*, conclude that vertebra which supports the greatest proportion of its neural arch, to be posterior to the adjoining one which supports the remaining small proportion. On this basis also I assume that the anterior sacral vertebra is deficient, if we may allow five to the Hylæosaur as to the other Dinosaurs.

The second sacral vertebra, then, is here broken across the middle of the body, exposing its solid minutely cellular central structure: its neural arch is too mutilated for profitable description: its base rests nearly equally on the second and third sacral bodies. The third neural arch, which exhibits a similar relative position, has its base extended half way down the inter-space; its strong transverse process extends outwards and forwards, and is at first contracted, then expands both transversely and vertically, most so in the latter direction, and is twisted obliquely, so that the lower end is directed downwards and forwards, and the upper and thicker end is bent obliquely backwards, until it meets and becomes anchylosed to the anterior production of the transverse process of the next vertebra behind: an elliptical space is thus produced, the axis of which is nearly vertical, and into this space the neural canal opens; the nerve being transmitted over the middle of the body of the vertebra, as in the sacrum of the *Megalosaurus*.

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* This description is taken from Nos. 2586 and 2125, parts of the same vertebra in the Mantellian Collection.

The upper and inner part of the base of the broad, oblique transverse process, or sacral rib, abuts against the base of the spinous process. There is no appearance of accessory spines, such as the sacrum of the *Megalosaurus* is complicated with.

The following are admeasurements of the present portion of the sacrum of the *Hylæosaurus*:—

	In.	Lin.
Length of the body of the third vertebra	2	0
Breadth of its articular end	2	0
Breadth of its middle part	1	4
Breadth of its inferior groove	0	4
Length of the transverse process	1	10
Antero-posterior diameter of the middle of process	0	4
Vertical diameter of base of process	1	6
Vertical diameter of expanded extremity	3	0
From the lower part of centrum to the origin of the spinous process	2	6

The spines appear to be anchylosed into a continuous ridge.

The anterior surface of the transverse process appears undulated by wide shallow depressions and intervening elevations.

Caudal vertebræ.—A proportion of the tail, to the extent of nearly six feet, and including about twenty-six vertebræ, discovered in a quarry in Tilgate Forest in the year 1837, is preserved in the Mantellian Collection. The transverse processes present almost Crocodilian proportions, in regard to their length, at the anterior part of this series, and may be discerned, though diminished to mere rudiments, in the small terminal vertebræ of the series. In the most perfect of the anterior vertebræ they are compressed vertically, but with convex, not flattened sides, and rounded edges, presenting an elliptical transverse section, and preserving the same breadth to their truncated extremity: they extend outwards, and are slightly bent forwards: the breadth of this vertebra between the extremities of the transverse processes is 11 inches. The neurapophysis is curved forwards from the base of the transverse process to form the anterior oblique process: its length from the extremity of this process to that of the posterior one is 3½ inches. The neurapophysis presents a simple convex external surface to the base of the spine: the antero-posterior extent of this process is two inches. The chevron bones are from four to five inches in length near the base of the tail; they may be distinguished, like the transverse processes, by their convex external surface; their base is open, not confluent as in the *Iguanodon*, and articulated to two distinct tubercles. Between these tubercles, which are placed at each end of the under surface of the centrum, there is a longitudinal sulcus. The transverse processes soon lose the slight anterior curve, stand straight out, decrease in length, and descend from the neurapophysis to the centrum as the vertebræ approach the end of the tail.

The chevron bones also decrease in length, but they expand in the antero-posterior direction at their unattached and dependent extremity, which is defined by a slight convex outline. The following admeasurements give the rate of decrease in length in the caudal vertebræ, taken at intervals of six joints:—

	In.	Lines.
Length of body of presumed 8th caudal	2	6
Length of body of presumed 14th caudal	2	4
Length of body of presumed 20th caudal	2	2

The sides of the slender posterior vertebræ are distinguished by a slight median expansion below the base of the rudimental transverse process, so that the surface, instead of being gently concave lengthwise, undulates by virtue of the middle elevation. I have not met with this character in the corresponding vertebræ of other Saurians. In the vertical direction the sides of the centrum in the posterior caudals converge at almost a right angle to the inferior groove. The greater breadth of the centrum, in proportion to its height, may still be discerned in the terminal caudal vertebræ: thus in the centrum 2 inches 2 lines long, the breadth was 1 inch 10 lines, and the height only 1 inch 3 lines.

Dermal scutes.—Unequivocal evidence that a dermal skeleton, analogous to that in the recent Crocodiles, was developed in the *Hylæosaurus*, was afforded by the discovery of bony scutes in the mass of vegetable matter removed in clearing the portion of the skeleton first described. Some of these detached bony plates still adhere to the caudal vertebræ, and may be observed to decrease in size as they approach the end of the tail. From their form, which is elliptical or circular, and from the absence of any surface indicating the overlapping of an adjoining scute, it may be inferred, that the bony plates in question studded in an unconnected order the skin of the Hylæosaur. The diameter of the largest of these scutes does not exceed three inches; the smallest present a diameter of one inch. They are flat on the under surface, convex with the summit developed into a tubercle in the smaller specimens, but which is less prominent in the larger ones: the outer surface is studded all over by very small tubercles: the inner surface presents the fine decussating straight lines, already noticed in the scutes of the *Goniopholis*.

By the kindness of Dr. Mantell, I have been favoured with the means of submitting the structure of a dermal scute to microscopical examination.

The medullary canals, which are stained brown, as if with the hematosine of the old reptile, differ from those of ordinary bone in the paucity or absence of concentric layers. They are situated in the interspaces of straight opake decussated filaments, which frequently seem to be cut short off close to the medullary canals. Very fine lines may be observed to radiate from some of the medullary canals: irregularly shaped, oblong and angular radiated cells are scattered through most parts of the osseous tissue, but they present less uniformity of size than do the Purkinjian cells in ordinary bone. The most striking characteristics of the dermal bone are the long straight spicular fibres which traverse it. and decussate each other in all directions, representing, as it seems, the ossified ligamentous fibres of the original corium.

Dermal spines?—On the left side of the thorax, partly overlying the left scapula and vertebral ribs, in the large slab of stone containing the anterior part of the skeleton, there are some large elongated, flattened pointed plates of bone, three of which seem to follow each other in natural succession. The length of the first of these plates is seventeen inches, the breadth of the base five inches, equal to the antero-posterior diameter of two vertebræ: they decrease somewhat rapidly in length, the second being fourteen inches long and the third eleven inches long; but slightly increase in breadth.

These remarkable bones are regarded by Dr. Mantell* as having formed part of a serrated fringe extended along the back of the animal, analogous to that of the *Cyclura* Lizard. This ingenious suggestion carries with it so high a degree of probability, that I had not thought of comparing the bones in question with any other part of the skeleton, until my attention was arrested by observing a want of symmetry in the form of the most perfect of them. They are nearly flat, but along the middle present a slight degree of concavity towards the observer, which, however, may be paralleled by a similar concavity on the opposite side buried in the stone; but the anterior or convex margin inclines from the middle line towards the concave side. With regard to their relative position to the rest of the skeleton, it must be observed that the ventral surface of this is exposed; so that the under parts of the bodies of the vertebræ are towards the observer, and their spines imbedded in the matrix. The coracoid and scapular arch are placed, as might be expected in a skeleton little disturbed and lying on its back, with their under surfaces towards the observer, and covering, like a buckler, a portion of the vertebræ and ribs. In this position we might look for a portion of the apparatus of the sternal or abdominal ribs, in the hope of discerning the modifications of these variable parts which might characterize a genus differing in many peculiarities from other known Saurians. Now it is with the apparatus of abdominal ribs, which present such a diversity of characters in other Saurians, that it may be useful to compare the long flattened bones in question, as well as with the supporting bones of a dorsal crest, in the event of a future discovery of a skeleton or portion of skeleton of the *Hylæosaurus* including these bones. The objection to their being abdominal ribs, which may be founded on their great relative breadth as compared with those ribs in other Saurians, and especially with the vertebral ribs of the *Hylæosaurus* itself, deserves due consideration; but the same objection applies to the bones in question as compared with the superadded spines in the Lizard with a dorsal fringe, or with the spines of the vertebræ themselves in the *Hylæosaurus*. For the dorsal dermal spines in the *Cyclura* correspond in number with the spines of the vertebræ which support them, while the base of each of the hypothetical dermal spines of the Hylæosaur extends over more than two vertebræ.

In the *Monotremata* (*Ornithorhynchus* and *Echidna*) the abdominal ribs are as much broader than the vertebral ribs as they would be in the *Hylæosaurus*, on the costal hypothesis of the detached bony plates here suggested; and, after the close repetition, in the *Ichthyosaurus*, of another of the remarkable deviations in those aberrant Mammals from the osteological type of their class, viz. in the structure of their sternal and scapular arch, the reappearance of the monotrematous modification of the sternal ribs in the present extinct reptile would not be surprising. The want of symmetry and the difference of size and form, above alluded to, in the four succeeding spine-shaped plates, agree better with the costal than the spinous hypothesis.

Whether the bones in question be dorsal spines or abdominal ribs, they have evidently been displaced from their natural position in the partial disarticulation of the entire skeleton prior to its immersion in the mud that has been subsequently hardened around it; but the degree of displacement has not been greater in the one case than in the other.

In offering, with due diffidence, a choice of opinions respecting the nature of these singular bones, I have been actuated solely with the view of accelerating the acquisition of the true one, which, it is obvious, will be more likely to be attained by the choice being present to the mind of subsequent fortunate discoverers of these remains of the *Hylæosaurus*, than if they were solely preoccupied by the hypothesis of the dorsal fringe. For example, it may lead to more careful noting of the constancy or otherwise of the unsymmetrical inclination of the convex margin of the spine, and whether they form, or are disposed in, pairs; which, on the costal hypothesis, may be expected, in the event of another skeleton being discovered.

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* Geology of South-east of England, p. 323. Wonders of Geology, vol. i. p. 402.

BONES OF THE EXTREMITIES.

Scapular arch.—The scapula of the *Hylæosaurus** is longer and narrower than in the Monitors and Iguanas, adhering in this respect to the Crocodilian type, but most resembling in the shape of its blade or body, that of the genus *Scincus*. It differs, however, from the scapulæ of all known reptiles, and indicates an approach to the Mammalian type, by the production of a strong obtuse acromial ridge, separated by a deep and wide groove from the humeral and coracoid articular surfaces. The blade of the scapula is long, flattened, slightly convex on the inner and proportionally concave on the outer surface: the anterior margin is convex, the posterior one concave; the upper extremity or base truncate, slightly convex, with the posterior angle a little produced, the anterior angle rounded off. On the outer side of the scapula two broad convex ridges descend and converge to form the beginning of a thick and strong spine, at fourteen inches distance from the base; this then expands into the thick acromial ridge, which extends transversely, and is continued forwards as a long subprismatic process from the anterior angle of the head of the scapula. This process, which appears likewise to be present in the scapula of the *Iguanodon*, perhaps also in the *Megalosaurus*, is broken off in the present specimen about four inches from the neck of the scapula, with which it forms a right angle. The acromion is perforated at the base of its anterior prolongation by a foramen analogous to the supraspinal one in the scapula of the Edentate Mammalia. Besides the scapulæ preserved in the connected part of the skeleton, there is, in the Mantellian Museum, a nearly entire and detached scapula of larger size, discovered, in connexion with many other bones of the skeleton, in a layer of blue clay near Bolney in Sussex, and indicating the connected part of the skeleton first discovered in 1832 to have belonged to an immature individual. The dimensions of this scapula are as follows:—

	In.	Lines.
Length of the scapula	18	0
Breadth of its base	8	0
Breadth of its neck	3	9
Thickness of its base	1	0
Thickness of its neck	2	6
Breadth of subacromial groove	2	0
Breadth of humeral articulation	4	0
Breadth of coracoid articulation	2	6

The *coracoids* present a much more simple form than in the *Megalosaurus*, and resemble those of the Scink and Chameleon, thus deviating in their great breadth, like the coracoids of the Enaliosaurs, from the Crocodilian type. In the portion of the skeleton the right coracoid is slightly bent out of place and thrust under the left one; and there is no trace of a sternal or entosternal bone in their interspace. The median margin of the coracoid describes an uninterrupted and full convex curve commencing at the angle dividing it from the scapular articular surface; but it is separated by a concavity or emargination from the articular surface for the humerus. It is perforated by a moderate sized elliptical canal, about two inches from the humeral articulation, and in this respect resembles the same bone in the Iguana, Monitors and Lizards, and differs from the Scinks and Chameleons. The antero-posterior extent of the coracoid in the connected portion of skeleton is eight inches; its transverse diameter five inches.

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* I have been favoured by Dr. Mantell with a drawing of the scapula figured by him in his recent Memoir on the *Hylæosaurus*, Phil. Trans., 1841, pl. x. fig. 10. The description above given of this, as of all the other Tilgate Saurians in the present Report, is taken from the original specimens in the British Museum, and other depositories of the Wealden fossils.

A humerus, and a phalangeal bone found with the scapula, near Bolney, are figured by Dr. Mantell in the Memoir of 1841.

Teeth of the Hylæosaur?—With regard to the *Hylæosaurus* Dr. Mantell observes, in his latest geological work, "the teeth are unknown; but in the quarries where the bones of that reptile were discovered, I have found teeth of a very peculiar form, which appear to have belonged to a reptile, and are entirely distinct from those of the *Megalosaurus*, *Iguanodon*, Crocodile and *Plesiosaurus*, whose remains occur in the Tilgate strata*." The form and structure of these teeth, which will be presently described, deviate too much from those of the Crocodilian family to make at all probable a reference of them to the genera Poikilopleuron, Streptospondylus, or Cetiosaur, which are much more closely allied to the Crocodilians than is the Hylæosaur. In the 'Geology of the South-east of England,' Dr. Mantell attributes these teeth, on the authority of M. Boué, to the *Cylindricodon*, a name by which Dr. Jäger distinguishes one of the species of his genus '*Phytosaurus*.' I have been favoured by Dr. Jäger with one of the bodies supposed to be the teeth of the *Cylindricodon* of the Wirtemberg Keuper, but it is merely the cast of a cylindrical cavity, consisting entirely of that mineral substance, without a trace of dental structure. The difference of form between the Wealden teeth now under consideration, and those on which the *Phytosaurus cylindricodon* of Jäger was founded, is pointed out in detail in my Odontography, and has been likewise appreciated by the estimable Palæontologist, M. Fischer de Waldheim, by whom their resemblance to certain Saurian teeth from the Ural Mountains, belonging to the genus *Rhopalodon*†, is indicated. From these teeth, however, the presumed Hylæosaurian teeth differ in having thick and flat instead of serrated coronal margins. The following is Dr. Mantell's original description of the teeth in question:—

"These teeth are about an inch and a quarter in length, and commence with a subcylindrical shank, which gradually enlarges into a kind of shoulder, terminating in an obtuse angular apex, the margins of which are more or less worn, as if the teeth had been placed alternately so as to meet at their edges, as in pl. ii. fig. 3. They are obscurely striated longitudinally, and have a thick coat of enamel: the crown of the tooth is solid, but the shank is more or less hollow. All the specimens appear as if they had been broken off close to the jaw; but they may have been separated by necrosis occasioned by the pressure of the supplementary teeth‡."

The following is the result of a microscopical examination of these teeth. The tooth consists of a body of dentine covered by a thick coating of clear structureless enamel, and surrounding a small central column of true bone, consisting of the ossified remains of the pulp, which presents the usual characters of the texture of the bone in the higher reptiles. The dentine differs, like that of existing Lacertians, from the dentine of the *Iguanodon* in the entire absence of the numerous medullary canals which form so striking a characteristic of the more gigantic Wealden reptile. The main calcigerous tubes are characterized by the slight degree of their primary inflections; they are continued in an unusually direct course from the pulp-cavity to the outer surface of the dentine, at nearly right angles with that surface, but slightly inclined towards the expanded summit of the tooth. They are chiefly remarkable for the large relative size of their secondary branches, which diverge from the trunks in irregular and broken curves, the concavity being always towards the pulp-cavity. In most parts of the tooth, the number of these branches obscures even the thinnest sections.

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* Wonders of Geology, vol. i. p. 403.

† Lettre sur le *Rhopalodon*, Moscow, 8vo, 1841.

‡ Geology of the South-east of England, p. 293.

The ossified pulp exhibits the parallel concentric layers of the ossified matter surrounding slender medullary canals, and interspersed with irregular elliptical radiated cells.

Jaw of the Hylæosaurus?—No. $\frac{422}{2422}$, in the Mantellian Collection, is a portion of the right ramus of the lower jaw, with characters distinguishing it from that of any other known Saurian; as, for example, its degree of curvature, indicating the lower jaw to have been bent down in an unusual degree, and the remarkable inequality of its external surface. This fragment is about three inches long, one inch seven lines deep at the hind part, and one inch five lines deep at the fore-part; flattened and smooth at the inner side, but having the outer side raised by the termination of a strong angular ridge at its lower and hinder part, and by a rough convex longitudinal ridge extending along its upper part; the surface of the jaw being concave above and below this ridge. The lower margin is thick and convex; the upper one is formed by a regular series of pretty close-set sockets, with the internal alveolar wall broken away, displaying their partitions; but with the outer wall entire, thin and slightly crenate at its upper margin.

At the hind part of this fragment the anterior extremity of the opercular piece is preserved; the rest is formed exclusively by the dentary piece: the area of the wide conical cavity in the interior of the jaw is exposed at the back part of the fragment; its apical termination is near the fore part. A succession of large vascular canals open obliquely forwards in the concavity above the upper oblique longitudinal ridge. The whole of the outer surface is minutely ridged and punctate.

The depth of the sockets bears a smaller proportion to that of the jaw than in modern Lacertians or Crocodiles, being about one-fourth of that depth: the partitions of the sockets, which are very regular in their breadth and depth, though they are more prominent than in the pleurodont Lizards, yet exhibit a fractured margin; there is no trace of a smooth natural surface of the bone in the interspace of the sockets; and at the part where the inner wall has been least mutilated, it nearly completes the socket and incloses the long and slender fang of the tooth. Whence, I conclude, that the entire jaw of the extinct reptile would have exhibited a series of true sockets, not depressions merely, as in the present mutilated fragment, and that it would have agreed with the *Megalosaurus* in presenting the thecodont mode of attachment of the teeth.

The crowns of all the teeth are broken off; the small sockets of reserve, exposed at the inner side of the base of the old sockets, do not contain any evidence of the species to which this fossil has belonged. In the absence of this characteristic part of the tooth, an element in guiding our choice between the *Iguanodon* and *Hylæosaurus* is given by the breadth of the interspaces of the sockets; these must bear relation to the breadth of the crowns of the teeth, if we suppose that they were in contact throughout the series, as in Lacertians. Now the teeth of the *Iguanodon*, and those which I have referred to the *Hylæosaurus*, differ in a marked degree in the breadth of the crown. The complicated and expanded crown of the Iguanodon's tooth is supported on a narrower stem; and the stems or fangs, if the crowns were in contact without overlapping, must have been separated by interspaces of proportional breadth, viz. twice their own breadth; but the thickness of the crown of the tooth of the *Iguanodon* renders it very unlikely that they did overlap each other. Now the crowns of the teeth of the Hylæosaur are expanded to such an extent, as, if in contact to require an interspace of the fangs, not broader than the fangs themselves; and the interspaces of the fangs in the fragment of jaw under consideration correspond with crowns of this breadth. The fangs of the teeth in the *Iguanodon* are conical, and more or less angular; in the teeth presumed to belong to the Hylæosaur the fangs are cylindrical; the sockets in the present fragment correspond with the latter form.

In my Odontography*, I adopted the opinion of Dr. Mantell† respecting the present fossil; but subsequent examination and consideration of its characters have led me to a different conclusion. It might, nevertheless, be urged that the teeth of the young *Iguanodon* may exhibit such modifications as would affect the validity of the objections here offered; but these, I think, establish the greater probability that the jaw in question originally contained teeth of the form of those that I have referred to the *Hylæosaurus*.

The remains of the *Hylæosaurus* have been discovered in the Wealden formation in the following localities: Tilgate Forest, Bolney and Battle.

IGUANODON MANTELLI, *Cuv.*

The bones of an enormous reptile, successively discovered in the Wealden strata by Dr. Mantell, interpreted by their discoverer with the aid of Cuvier and Clift‡, named *Iguanodon* by Conybeare§, lastly found in juxtaposition to the extent of nearly half the skeleton, in the green-sand quarries of Mr. Benstead, offer not the least marvellous or significant evidences of the inhabitants of the now temperate latitudes during the earlier oolitic periods of the formation of the earth's crust.

With vertebræ subconcave at both articular extremities, having, in the dorsal region, lofty and expanded neural arches, and doubly articulated ribs, and characterized in the sacral region by their unusual number and complication of structure; with a Lacertian pectoral arch and unusually large bones of the extremities excavated by large medullary cavities and adapted for terrestrial progression;—the *Iguanodon* was also distinguished by teeth, resembling in shape those of the Iguana, but in structure differing from the teeth of every other known Reptile, and unequivocally indicating the former existence, in the Dinosaurian Order, of a gigantic representative of the small group of living lizards which subsist on vegetable substances.

Of this remarkable Reptile, the results of personal examination of almost all the recognisable remains that have hitherto been collected in public or private museums, are here given.

Teeth.—The value of the ordinary external characters of the teeth of the oviparous Vertebrata has never perhaps been placed in so striking a point of view as in the leading steps to the discovery of the *Iguanodon*, which cannot be better recounted than in the words of Dr. Mantell.

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* Part ii. p. 248.

† Wonders of Geology, vol. i. p. 393.

‡ See Philosophical Transactions, 1825, "Notice on the *Iguanodon*, by Gideon Mantell, F.L.S."

§ "The name *Iguanodon*, derived from the form of the teeth (and which I have adopted at the suggestion of the Rev. W. Conybeare), will not, it is presumed, be deemed objectionable."—*Loc. cit.*

After noticing the ordinary organic remains which characterize the sandstone of the Tilgate Forest, and his discovery, in the summer of 1822, of other teeth distinguished by novel and remarkable characters, the indefatigable explorer of the Wealden proceeds to state*,—

"As these teeth were distinct from any that had previously come under my notice, I felt anxious to submit them to the examination of persons whose knowledge and means of observation were more extensive than my own. I therefore transmitted specimens to some of the most eminent naturalists in this country and on the continent. But although my communications were acknowledged with that candour and liberality which constantly characterizes the intercourse of scientific men, yet no light was thrown upon the subject, except by the illustrious Baron Cuvier, whose opinions will best appear by the following extract from the correspondence with which he honoured me:—

"'Ces dents me sont certainement inconnues; elles ne sont point d'un animal carnassier, et cependant je crois qu'elles appartiennent, vu leur peu de complication, leur dentelure sur les bords, et la couche mince d'émail qui les revêt, à l'ordre des reptiles; à l'apparence extérieure on pourrait aussi les prendre pour des dents de poissons, analogues aux tetrodons, ou aux diodons; mais leur structure intérieure est fort différente de celles-là. N'aurions-nous pas ici un animal nouveau, un reptile herbivore? et de même qu'actuellement chez les mammifères terrestres, c'est parmi les herbivores que l'on trouve les espèces à plus grande taille, de même aussi chez les reptiles d'autrefois, alors qu'ils étaient les seuls animaux terrestres, les plus grands d'entr'eux ne se seraient-ils point nourris de végétaux? Une partie des grands os que vous possédez appartiendrait à cet animal unique, jusqu'à présent, dans son genre. Le temps *con*firmera ou *in*firmera cette idée, puisqu'il est impossible qu'on ne trouve pas un jour une partie de la squelette réunie à des portions de mâchoires portant des dents. C'est ce dernier objet surtout qu'il s'agit de rechercher avec le plus de persévérance.'

"These remarks," Dr. Mantell proceeds to say, "induced me to pursue my investigations with increased assiduity, but hitherto they have not been attended with the desired success, no connected portion of the skeleton having been discovered. Among the specimens lately collected, some, however, were so perfect, that I resolved to avail myself of the obliging offer of Mr. Clift (to whose kindness and liberality I hold myself particularly indebted), to assist me in comparing the fossil teeth with those of the recent Lacertæ in the Museum of the Royal College of Surgeons. The result of this examination proved highly satisfactory, for in an Iguana which Mr. Stutchbury had prepared to present to the College, we discovered teeth possessing the form and structure of the fossil specimens."

The important difference which the fossil teeth presented in the form of their grinding surface was afterwards pointed out by Cuvier†, and recognised by Dr. Mantell‡, and the combination of this dental distinction with the vertebral and costal characters, which prove the *Iguanodon* not to have belonged to the same group of Saurians as that which includes the Iguana and other modern lizards, rendered it highly desirable to ascertain, by the improved modes of investigating dental structure, the actual amount of correspondence between the *Iguanodon* and Iguana in this respect. This I have endeavoured to do in my general description of the Teeth of Reptiles§, from which the following account is abridged.

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* Notice on the *Iguanodon*, Phil. Trans. 1825.

† Ossemens Fossiles, 1824, vol. v. part ii. p. 351.

‡ Illustrations of the Geology of Sussex, 4to, 1827.

§ Odontography, part ii. p. 249; and Transactions of the British Association, 1838.

The teeth of the *Iguanodon*, though resembling most closely those of the Iguana, do not present an exact magnified image of them, but differ in the greater relative thickness of the crown, its more complicated external surface, and, still more essentially, in a modification of the internal structure, by which the *Iguanodon* equally deviates from every other known reptile.

As in the Iguana, the base of the tooth is elongated and contracted, while the crown is expanded, and smoothly convex on the inner side; when first formed it is acuminated, compressed, its sloping sides serrated, and its external surface traversed by a median longitudinal ridge, and coated by a layer of enamel, but beyond this point the description of the tooth of the *Iguanodon* indicates characters peculiar to that genus. In most of the teeth that have hitherto been found, three longitudinal ridges traverse the outer surface of the crown, one on each side of the median primitive ridge; these are separated from each other and from the serrated margins of the crown by four wide and smooth longitudinal grooves. The relative width of these grooves varies in different teeth; sometimes a fourth small longitudinal ridge is developed on the outer side of the crown. The marginal serrations, which, at first sight, appear to be simple notches, as in the Iguana, present under a low magnifying power the form of transverse ridges, themselves notched, so as to resemble the mammillated margins of the unworn plates of the elephant's grinder: slight grooves lead from the interspaces of these notches upon the sides of the marginal ridges. These ridges or dentations do not extend beyond the expanded part of the crown: the longitudinal ridges are continued further down, especially the median ones, which do not subside till the fang of the tooth begins to assume its subcylindrical form. The tooth at first increases both in breadth and thickness; it then diminishes in breadth, but its thickness goes on increasing; in the larger and fully formed teeth, the fang decreases in every diameter, and sometimes tapers almost to a point. The smooth unbroken surface of such fangs indicates that they did not adhere to the inner side of the maxillæ, as in the Iguana, but were placed in separate alveoli, as in the Crocodile and Megalosaur: such support would appear, indeed, to be indispensable to teeth so worn by mastication as those of the *Iguanodon*.

The apex of the tooth soon begins to be worn away, and it would appear, by many specimens, that the teeth were retained until nearly the whole of the crown had yielded to the daily abrasion. In these teeth, however, the deep excavation of the remaining fang plainly bespeaks the progress of the successional tooth prepared to supply the place of the worn out grinder. At the earlier stages of abrasion a sharp edge is maintained at the external part of the tooth by means of the enamel which covers that surface of the crown; the prominent ridges upon that surface give a sinuous contour to the middle of the cutting edge, whilst its sides are jagged by the lateral serrations: the adaptation of this admirable dental instrument to the cropping and comminution of such tough vegetable food as the *Clathrariæ* and similar plants, which are found buried with the *Iguanodon*, is pointed out by Dr. Buckland, with his usual felicity of illustration, in his 'Bridgewater Treatise,' vol. i. p. 246.

When the crown is worn away beyond the enamel, it presents a broad and nearly horizontal grinding surface, and now another dental substance is brought into use to give an inequality to that surface; this is the ossified remnant of the pulp, which, being firmer than the surrounding dentine, forms a slight transverse ridge in the middle of the grinding surface: the tooth in this stage has exchanged the functions of an incisor for that of a molar, and is prepared to give the final compression, or comminution, to the coarsely divided vegetable matters.

The marginal edge of the incisive condition of the tooth and the median ridge of the molar stage are more effectually established by the introduction of a modification into the texture of the dentine, by which it is rendered softer than in the existing Iguanæ and other reptiles, and more easily worn away: this is effected by an arrest of the calcifying process along certain cylindrical tracts of the pulp, which is thus continued, in the form of medullary canals, analogous to those in the soft dentine of the Megatherium's grinder, from the central cavity, at pretty regular intervals, parallel with the calcigerous tubes, nearly to the surface of the tooth. The medullary canals radiate from the internal and lateral sides of the pulp-cavity, and are confined to the dentine forming the corresponding walls of the tooth: their diameter is $\frac{1}{1\cdot250}$th of an inch: they are separated by pretty regular intervals equal to from six to eight of their own diameters; they sometimes divide once in their course. Each medullary canal is surrounded by a clear space; its cavity was occupied in the section described by a substance of a deeper yellow colour than the rest of the dentine.

The calcigerous tubes present a diameter of $\frac{1}{25,000}$th of an inch, with interspaces equal to about four of their diameters. At the first part of their course, near the pulp-cavity, they are bent in strong undulations, but afterwards proceed in slight and regular primary curves, or in nearly straight lines to the periphery of the tooth. When viewed in a longitudinal section of the tooth, the concavity of the primary curvature is turned towards the base of the tooth: the lowest tubes are inclined towards the root, the rest have a general direction at right angles to the axis of the tooth; the few calcigerous tubes, which proceed vertically to the apex, are soon worn away, and can be seen only in a section of the apical part of the crown of an incompletely developed tooth. The secondary undulations of each tooth are regular and very minute. The branches, both primary and secondary, of the calcigerous tubes are sent off from the concave side of the main inflections; the minute secondary branches are remarkable at certain parts of the tooth for their flexuous ramifications, anastomoses, and dilatations into minute calcigerous cells, which take place along nearly parallel lines for a limited extent of the course of the main tubes. The appearance of interruption in the course of the calcigerous tubes, occasioned by this modification of their secondary branches, is represented by the irregularly dotted tracts in the figure. This modification must contribute, with the medullary canals, though in a minor degree, in producing that inequality of texture and of density in the dentine, which renders the broad and thick tooth of the *Iguanodon* more efficient as a triturating instrument.

The enamel which invests the harder dentine, forming the outer side of the tooth, presents the same peculiar dirty brown colour, when viewed by transmitted light, as in most other teeth: very minute and scarcely perceptible undulating fibres, running vertically to the surface of the tooth, is the only structure I have been able to detect in it.

The remains of the pulp in the contracted cavity of the completely formed tooth are converted into a dense but true osseous substance, characterized by minute elliptical radiated cells, whose long axis is parallel with the plane of the concentric lamellæ, which surround the few and contracted medullary canals in this substance.

The microscopical examination of the structure of the Iguanodon's teeth thus contributes additional evidence of the perfection of their adaptation to the offices to which their more obvious characters had indicated them to have been destined.

To preserve a trenchant edge, a partial coating of enamel is applied; and, that the thick body of the tooth might be worn away in a more regularly oblique plane, the dentine is rendered softer as it recedes from the enameled edge by the simple contrivance of arresting the calcifying process along certain tracts of the inner wall of the tooth. When attrition has at length exhausted the enamel, and the tooth is limited to its function as a grinder, a third substance has been prepared in the ossified remnant of the pulp to add to the efficiency of the dental instrument in its final capacity. And if the following reflections were natural and just after a review of the external characters of the dental organs of the *Iguanodon*, their truth and beauty become still more manifest as our knowledge of their subject becomes more particular and exact:—

"In this curious piece of animal mechanism we find a varied adjustment of all parts and proportions of the tooth, to the exercise of peculiar functions, attended by compensations adapted to shifting conditions of the instrument, during different stages of its consumption. And we must estimate the works of nature by a different standard from that which we apply to the productions of human art, if we can view such examples of mechanical contrivance, united with so much economy of expenditure, and with such anticipated adaptations to varying conditions in their application, without feeling a profound conviction that all this adjustment has resulted from design and high intelligence." —*Buckland's Bridgewater Treatise*, vol. i. p. 249.

Head.—Two fragments of jaw with alveoli, in the Mantellian Collection, are referred by its founder to the *Iguanodon*: in neither of them, unfortunately, is a tooth with the characteristic crown preserved: the size of these specimens proves them to have belonged, if to this genus, then to young individuals. The smaller fragment is described in this Report under the head of *Hylæosaurus*, on account of the cylindrical, equal, and straight form of the remaining fangs. These parts correspond with the fangs of the teeth which I suppose to belong to the *Hylæosaurus*, rather than with those of the *Iguanodon*, which are angular, curved, taper towards a point, and support crowns so expanded, as to require greater intervals between their fangs than in the fossil. It is just possible that these differences may depend on age*.

Tympanic bone.—A reptile with vertebræ and ribs resembling in their chief characters those of the cœlospondylian Crocodiles, and with distinctive peculiarities, in which the Lacertians by no means participate, might reasonably be conjectured to resemble the Crocodiles in the form of the tympanic bone; and if the reptile in question used its teeth for masticating hard vegetable substances, we might with more reason expect that the bony pillar supporting the lower jaw should be firmly and immoveably fixed through its whole length, like the tympanic bone of the Crocodilians, and not be loosely suspended to the skull by a single extremity, as in the Iguana and other Lacertians. A very remarkable bone discovered in the Tilgate strata, figured by Dr. Mantell in the 'Geology of the South-east of England,' pl. ii. fig. 5, the resemblance of which to the 'os quadratum,' or tympanic bone of birds, was first suggested by Dr. Hodgkin, is assigned to the *Iguanodon* by Dr. Mantell. He accurately describes it "as forming a thick pillar or column, which is contracted in the middle, and terminates at both extremities in an elliptical and nearly flat surface." In the Iguana and other reptiles the lower end of the tympanic bone is terminated by a convex trochlea, which is received into a corresponding cavity in the lower jaw. Is the modification of the bone in question, assuming it to belong to the *Iguanodon*, indicative of a peculiarity of the joint of the lower jaw as remarkable as the structure of the teeth, and correlated to their masticatory uses? "Two lateral processes, or *alæ*, pass off obliquely, and are small in proportion to the size of the column; on placing these bones beside the os tympani of an Iguana, we at once perceive that the relative proportions of these parts are reversed; for in the recent animal the pillar is small and the lateral processes large. From the great size of the body of the fossil, and the extreme thinness of its walls, the *tympanic cellulæ* must have been of considerable magnitude, and have constituted a large portion of the auditory cavities. Pl. ii. fig. 1., (fig. 5 is meant,) accurately represents the most perfect specimen in my cabinet; it is 6 inches high, and 5½ inches wide at the longest diameter of the extremity of the body. It exceeds in magnitude the corresponding bone of the *Mosasaurus*, and is fourteen times as large as the same bone in an Iguana 4 feet long." *Loc. cit.*, p. 306.

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* In the Monitor-lizards of the modern genera *Thorictes* and *Crocodilurus*, the posterior teeth in the young individuals have more or less compressed and tri-cuspidate crowns, but in the old animals they have round obtuse crowns, adapted for true mastication. Some modification analogous to this may take place in the *Iguanodon*.

Vertebral Column.—The vertebræ of the *Iguanodon* have their bodies terminated by flat or slightly concave articular surfaces*, and their sides flat or slightly convex vertically, moderately concave lengthwise or in the axis of the vertebra; the sides converge more or less towards the under surface, and the body accordingly presents more or less the form of a wedge, with its edge obtuse or flattened in the dorsal vertebræ, but slightly concave, and with its anterior and posterior angles truncated in the caudal vertebræ†. The contour of the terminal surfaces is nearly circular, with the vertical slightly exceeding the transverse diameter. The neural arch of the dorsal vertebræ presents the complicated exterior, the great height and superior expansion, which characterize these vertebræ in other Dinosaurs: the base of each neurapophysis equals, or nearly equals, the antero-posterior extent of the centrum, but immediately contracts in this direction from the posterior margin, which then curves backwards as it inclines towards the opposite neurapophysis, and the conjoined laminæ are developed beyond the posterior end of the centrum to an extent varying in the different regions of the spine. In the dorsal vertebræ the bases of the neurapophyses are developed transversely inwards, so as to meet and join each other below the spinal canal: the hæmapophyses present an analogous structure through a great part of the tail, the bases of each pair, as well as the apices, being united together, and the chevron bones, thus formed, are perforated instead of being notched for the passage of the great blood-vessels. The neurapophyses are commonly anchylosed to the centrum, with a persistent trace of the suture. The transverse processes are straight, and of great length in the vertebræ from the middle of the trunk, indicating there a considerable expanse of the abdominal cavity, adapted for the lodgement of the capacious viscera of a herbivorous feeder. The spinous processes rise to a considerable height in the dorsal, as well as in the anterior caudal vertebræ. The exterior surface of the vertebræ is impressed with fine striations, which are mostly longitudinal in the centrum; so that fragments may thus be distinguished from the characteristically smooth and polished vertebræ of the *Megalosaurus*. The antero-posterior diameter of the largest vertebræ of the *Iguanodon* which I have yet seen is 4½ inches; the most usual size is 4 inches.

Having premised these general characters of the vertebræ of the *Iguanodon*, there next remain to be considered the modifications by which they are distinguished in different regions of the spinal column. Hitherto I have not met with any specimen of a cervical vertebra; the comparatively small fractured vertebra, Nos. $\frac{437}{2437}$ and $\frac{438}{2438}$, "Axis of the *Iguanodon*," Mantell. Catal., is an ordinary, or more posterior, cervical vertebra of a large Crocodilian Reptile, which, if not belonging to the *Poikilopleuron*, indicates a species distinguishable from all other known Saurians*. The large cervical vertebræ with ball-and-socket articular surfaces, agreeing with the *Iguanodon* in size, have been shown to have these surfaces the reverse in position to those in the Iguanæ and modern Saurians, and to belong to the genus *Streptospondylus*. The desirable knowledge, therefore, of the anatomy of that region of the spine in the *Iguanodon*, which in other Saurians is usually distinguished by its well-marked and varied characters, remains to be acquired.

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* The plano-concave vertebræ in the Mantellian Collection, British Museum, belong to the *Cetiosaurus*.

† The large vertebræ from the Wealden, with obscurely quadrangular or hexagonal bodies, which are rather convex or flat on one side and concave on the other, belong to the *Cetiosaurus*.

Costal or dorsal vertebræ†.—Towards the middle or anterior part of this region the bodies of the vertebræ are laterally compressed, and meet below at an obtuse ridge. Through, apparently, a considerable proportion of the dorsal region of the spine, the neurapophyses rise vertically to a height equal to that of the centrum, and expand into a broad and strong platform, the upper surface of which is slightly concave transversely, and arched from behind downwards and forwards in a regular curve; this platform is supported by a strong vertical buttress on each side, and sends upwards from the whole of its middle line a thick, broad and high spinous process. Two oblique, flat, articular processes look downwards and outwards from the posterior angles of the platform; and the corresponding anterior oblique processes, having their flat articular surfaces looking upwards and inwards, and inclining to each other at a right angle, terminate the contracted anterior part of the platform, and do not project beyond it as two distinct processes separated by a median fissure. They are not continued beyond the anterior end of the body of the vertebræ, and consequently the posterior processes overhang the hinder surface of the centrum in order to rest upon the oblique processes of the vertebra next behind. In the anterior dorsal vertebræ the body supports a large and well-marked articular surface on each side, for the head of the rib; and a long and strong transverse process is developed from each neurapophysis against the end of which the tubercle of the rib abuts, as in the Crocodile. In the hinder costal vertebræ the long transverse process is gradually narrowed to its extremity, which is abruptly truncated, and has a right-angled notch at the anterior part; the curtailed neck of the rib, no longer expanded into a head or joined to the body of the vertebra, is fitted into this notch, and the broad and flat surface, at right angles to the neck, is adapted to the extremity of the transverse process.

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* A portion of this vertebra is alluded to at p. 137, and figured at pl. ix., fig. 1, of Dr. Mantell's Memoir on the *Iguanodon*, published in the Philosophical Transactions for the present year, 1841, as the "atlas of a young *Iguanodon*;" its position in the neck has been apparently determined by the resemblance of the cast of calcareous spar, which fills up the spinal canal, to the medulla oblongata. This resemblance arises from the expansion of the open ends of the canal; in which expansions, in the recent Crocodile, the contained spinal chord does not, however, in the least degree participate. The longitudinal fissure in the cast is due to a corresponding ridge of bone projecting from the inner surface of the contiguous wall of the spinal canal; doubtless giving attachment to the dura mater of the chord, but not impressing the chord itself. The external surface of the vertebra exhibits an upper and a lower transverse process for the attachment of a bilobed cervical rib, which unequivocally demonstrates it not to agree with the Lacertian type of structure.

† In the Memoir in the Philosophical Transactions, 1841, above quoted, Dr. Mantell says, "The usual characters of the dorsal and caudal vertebræ of the *Iguanadon* have been pointed out in my former works," and refers to the 'Fossils of Tilgate Forest,' and the 'Geology of the South-east of England,' p. 136. I have again, therefore, carefully perused the passages in which the structure of the vertebræ from the Wealden strata is alluded to in those valuable works, in the hope that the present tedious section of my Report might be cancelled; but they leave the same doubt, which their first perusal occasioned, as to whether the author intended to attribute to the vertebræ of the *Iguanodon* the characters of those of the second system of Wealden vertebræ, viz. *Cetiosaurus*; or those of the fourth system, viz. *Streptospondylus*. See Geology of the South-east of England, p. 306. M. H. v. Meyer adopts the former, or the Cetiosaurian type, for his characters of the Iguanodon's vertebræ, from the works to which Dr. Mantell refers. The six caudal vertebræ of the *Iguanodon* described in the Memoir of 1841, are referred to, in the 'Geology of the South-east of England,' at the conclusion of the account of the *Hylæosaurus*, and the accomplished author there states, "The bodies of these vertebræ, like those of the newly-discovered reptile, are slightly concave at both extremities," which is one of the characters whereby they might be distinguished from the vertebræ of the *Cetiosaurus*.

We seek in vain, in the existing Iguana, for such modes of articulation of the ribs as have here been described, while they are common to Crocodiles with the Dinosaurs. The fact of the complete inclosure of the spinal canal by the meeting and confluence of the bases of the neurapophyses beneath it, was first brought to my attention by the appearances in the body of a dorsal vertebra of the great Horsham *Iguanodon*, in the collection of Mr. Holmes. This centrum, which measures 4½ inches in length and 5 inches across its articular extremity, presented only a slight trace of the impression of the spinal canal at the anterior part of its upper surface, the rest being occupied by a slightly concave, continuous, rough articular surface. The deficiency of this vertebra was supplied by a fine specimen in Mr. Saull's collection of the separate neural arch of a dorsal vertebra of a corresponding size, which seemed to have been detached from a natural articulation. I saw with much interest that the bases of the neurapophyses met and joined each other below the spinal canal along the posterior half of their longitudinal extent, presenting at their under part a continuous slightly convex surface, which must have left a corresponding concave rough articular surface upon the upper part of the centrum, like that exhibited by the Horsham vertebral body. The base of each neurapophysis, which is longer than it is wide, describes a slight curve, convex in the antero-posterior direction, downwards or towards the centrum. The spinal canal is nearly cylindrical, very slightly expanded at the two extremities; its diameter 1 inch 5 lines. The chief buttress of the spinal platform rises from the posterior and outer part of the base of the neurapophysis, and ascends almost vertically, slightly inclining forwards; it is compressed, with its plane transverse to the axis of the vertebra; it expands as it blends with the under part of the broad platform, half-way between the anterior and posterior boundaries of that remarkable part of the neurapophysis. A second buttress rises from the anterior part of the base of the neurapophysis, and ascends vertically to the upper and outer end of the anterior oblique processes. The base of the transverse process is situated above the converging point of the two buttresses. In the interspace of the two buttresses of the anterior dorsal vertebræ there is a large oval articular surface, convex at the anterior and concave at the posterior part, which has afforded a lodgement to the head of an enormous rib. The oblique or articular processes, directed as described in the general observations on the vertebræ of the *Iguanodon*, converge and meet at nearly a right angle. There is a wide depression at the posterior broad part of the base of the spine, and a wide and deep fossa between the posterior buttress and the posterior oblique process. The base of the spine, as it extends forwards along the middle of the broad platform, descends with a graceful curve to the interspace of the anterior oblique processes. The platform recedes on each side from the base of the broad spine with a regular concavity to its plane; its surface is coarsely striated transversely.

The following are dimensions of this interesting fossil:—

	In.	Lin.
Length of the base of the neurapophysis*	4	6
From the base of the neurapophysis to the middle of the base of spinous process	5	0
From the base of the neurapophysis to the posterior part of the base of spinous process	6	0
From the base of the neurapophysis to the anterior part of the base of spinous process	3	6
Antero-posterior extent of base of spinous process	6	6
Transverse diameter of spinal platform	8	6
Transverse diameter of conjoined bases of neurapophyses†	4	0
Extent of spinal platform beyond hind part of base of neurapophysis	4	0

The spinous process is broken off near its base in this specimen, which is otherwise remarkably entire, considering that it was washed out of the submerged beds of the Wealden and cast on the south shore of the Isle of Wight. It was found near Culver Cliff.

The characters thus obtained from two different parts of the vertebræ of two Iguanodons from distant localities, certified to belong to that genus from the association of one of the parts, viz. the vertebral centrum, with many other characteristic bones of that reptile, have their value increased from the circumstance of the obscure and unsatisfactory manner in which the vertebral characters are exhibited in the celebrated specimen from the Maidstone quarry. The eight vertebræ originally forming a continuous series in this specimen are from about the middle of the back; the antero-posterior diameter of each is 3½ inches. Little more can be determined from these or from the detached and crushed dorsal vertebræ in this specimen, except the flattening of the sides of the vertebræ and their convergence to the lower surface, the slight concavity of both articular extremities, the height of the neural arch, and the strength and length of the transverse and spinous processes.

With the evidence afforded by the previously described specimens, the characters afforded by the following detached vertebræ from the Tilgate strata may with confidence be applied to the further elucidation of the osteology of the *Iguanodon*.

An anterior dorsal vertebra (No. $\frac{160}{2160}$, Mantellian Collection), having the following dimensions of the centrum,—

	In.	Lin.
Antero-posterior diameter	3	11
Vertical diameter of articular end	4	1
Transverse diameter of articular end	3	2

measures, from its under surface to the posterior part of the base of the spinous process, 8 inches. The broad and high neural arch is anchylosed with the centrum, but the nearly straight line of suture is indicated by numerous puckered rugæ and striæ. The transverse process extends from the side of the neurapophysis; its base is vertically oval, measuring 2½ inches by 2 inches. The neurapophysis expands above this surface into a broad platform, with a thick rough external free border, probably fractured. The platform is supported by a buttress-like ridge, rising vertically from the posterior angle of the base of the neurapophysis, and expanding as it ascends to blend with the under part of the overhanging platform. Behind this buttress is a wide and deep depression, and the neurapophysis extends backwards to form the posterior articular processes which project 1½ inch beyond the hind surface of the centrum. The antero-posterior extent of the neurapophysial platform is 6 inches; the dimensions of the oval articular surfaces of the oblique processes are 2 inches by 2½ inches; the inferior margins of the posterior processes are separated by a groove. A smaller anterior ridge extends along the anterior part of the neurapophysis. The base of the spinous process extends from the posterior triangular interspace of the oblique processes forwards and downwards along the curve of the supporting platform; the thickness of the spine, which is 1 inch at the posterior part of the base, gradually diminishes towards the fore part of the vertebra. The anterior oblique processes form the sides of an angular depression in front of the base of the spine.

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* This doubtless gives the length of the centrum to which it was attached.

† At their anterior and broader part.

The spinal platform of the *Iguanodon* differs from that of the *Megalosaurus* in its greater relative antero-posterior extent, arising from its being extended further back; the platform is also raised higher above the centrum.

No. $\frac{556}{2550}$, Mantellian Collection, is a dorsal vertebra, posterior in situation to the preceding, and from an individual of the same size. The neural arch is anchylosed, but the sutural line is obvious. The surface for the head of the rib on the side of the neurapophysis is smaller, and a transverse process begins to be developed above that surface, throwing its aspect somewhat downwards. The costal surface is separated in this as in the preceding vertebra by a strong vertical ridge or buttress from the wide depression below the posterior part of the base of the spine. The angle between the oblique processes is rather more open. The spinous process of this vertebra, almost entire, is detached from the neural platform, but is cemented to the same mass of stone: it is 9 inches in height and 3 in breadth, or antero-posterior extent; the summit is, however, wanting. The following are other dimensions of the present vertebra:—

	In.	Lines.
Antero-posterior extent of the body	3	10
Vertical diameter of the body	3	9
Transverse diameter of the body	3	7

The sides of the centrum are as usual concave lengthwise, but are slightly convex vertically, and converge to the lower surface, which is formed by an obtuse ridge.

In a dorsal vertebra of the Horsham *Iguanodon* in Mr. Holmes's collection, from apparently the middle of the back, the spinous process, which is 8 inches in length, expands gradually in breadth and thickness as it ascends to its truncated summit, the antero-posterior diameter of which is 4 inches, its transverse diameter or thickness being 1 inch 6 lines.

In a series of eight posterior dorsal vertebræ, measuring together 1 foot, and consequently from a young *Iguanodon* in Mr. Holmes's collection, the spinous process of the most anterior one is, in antero-posterior diameter, 7 lines, but increases in the other vertebræ to 15 lines, which shows a somewhat rapid change of character.

Sacral Vertebræ.—The highly remarkable and characteristic structure of the sacrum of the *Megalosaurus*, and the strong indications of close affinity between this gigantic carnivorous reptile and the still more colossal herbivorous *Iguanodon*, which the structure of their costal vertebræ, of their ribs, and of the larger bones of their extremities afford, made it very desirable to ascertain whether the *Iguanodon* deviated in the same manner from other Saurians, existing and extinct, in the extent and structure of the sacral region of the spine.

The collection of the remains of the *Iguanodon* in the British Museum does not include this characteristic part of the skeleton; it does not form part of the series of bones obtained by Mr. Holmes from the Wealden Quarry at Horsham; but in the collection of rolled bones of the great Wealden Saurians—*Cetiosaurus*, *Streptospondylus*, and *Iguanodon*—in the museum of Mr. Saull, there is a fine specimen of the sacrum with one of the iliac bones attached, which, in the proportions of the vertebræ and the form of the ilium, agrees with the known characters of the *Iguanodon*.

This instructive specimen consists of five vertebræ anchylosed together by the articular surfaces of their bodies and by their spinous processes, which seem to form a continuous thick median ridge of bone. The five vertebræ measure 17 inches in length. The articular extremity of the terminal sacral vertebra is very slightly concave and subcircular, measuring 3 inches in both vertical and transverse diameter. The bodies of the dorsal vertebræ are compressed at their middle part, and broader below than in the dorsal region, and concave in the direction of their axis, the concavities being separated by the broad prominent convex transverse ridges formed by the anchylosed and ossified intervertebral spaces. The contour of the under part of the sacrum thus forms an undulating line. The lateral and inferior surfaces are separated by a more angular prominence of the centrum, the under surface is less convex transversely, and the whole centrum is shorter in proportion to its depth and breadth, than in the *Megalosaurus*. The neurapophyses present the same remarkable modification in regard to their relations to the body of the vertebra as in the *Megalosaurus*, having shifted their position from the upper surface of a single centrum to the interspace of two, resting on proportions of these, which are more nearly equal, as the vertebræ are nearer the middle of the sacrum. The nerves were compelled therefore to escape from the spinal canal over the body of the vertebra, more or less near its middle, and they impress the upper surface there with a smooth canal.

The strong, vertically compressed, transverse processes, or sacral ribs, rise from the bases of the neurapophyses, and their origin extends upwards upon the spine, and downwards upon the sides of the contiguous vertebral bodies and intervertebral space; in the specimen described they are firmly anchylosed to all these parts, extend outwards and expand at their extremities, four of which meet, join, and form an elongated tract of varying breadth to which the ilium is firmly attached. The length of the largest penultimate transverse process was 5 inches 8 lines, its vertical breadth at the middle 3 inches, its thickness here 1 inch. The adjoining (last) transverse process was 5 inches in length; the interspaces of the transverse processes equalled from 2½ inches to 2 inches. The sacrum increases in breadth posteriorly; its transverse diameter, including the anchylosed ilia taken at the posterior part of the acetabulum, is 13 inches, at the anterior part of the sacrum only 8 inches. The proportion of the spine thus grasped, as it were, by the iliac bones, which transmit the weight of the body upon the thigh-bones, corresponds with the mass which is to be sustained and moved; and the size and structure of the sacrum indicate, with those of the femur and tibia, the adaptation of the present great herbivorous Saurian for terrestrial life.

No. $\frac{127}{2127}$, Mantellian Collection, is the centrum of a sacral vertebra of a subquadrate form, with a broad and flattened inferior surface, slightly concave antero-posteriorly. The upper surface is excavated by a wide and moderately deep canal, indicating the unusual size, for Reptiles, of the sacral portion of the spinal chord. The anterior and posterior parts of the sides of this centrum are raised, so as to form projecting sub-triangular rough articular surfaces, continued upon the margins of the spinal canal, evidently for the attachment of the neurapophyses and the heads of the strong sacral ribs. The interspace of these anterior and posterior neurapophysial surfaces is formed by a smooth oblique groove, connecting the smooth surface of the spinal canal with that of the free lateral surface of the vertebra, and indicating the place of exit of the sacral nerves, which is necessarily in this unusual situation, because the ordinary holes of conjugation must have been obliterated by the impaction of the bases of the neurapophyses between the contiguous extremities of the bodies of the sacral vertebræ.

The anterior and posterior articular extremities of the present interesting fossil equally bespeak the peculiar character of the sacral vertebræ of the *Dinosauria*. They are impressed by coarse straight ridges and grooves radiating from near the upper part of the surface, like those on the corresponding part of a cetaceous vertebra when the epiphysial articular extremity is removed. These inequalities are here, doubtless, preparatory to that anchylosis by which the sacral vertebræ are compacted together in the mature Dinosaurs.

	In.	Lines.
The length of this vertebra	2	10
The height	2	6
The breadth of anterior articular end	3	0
The breadth of middle	2	2
Antero-posterior diameter of anterior costal surface .	1	7
Antero-posterior diameter of posterior one	1	0
Breadth of spinal canal	1	5
Breadth of canal of sacral nerve	0	4

From its separated condition, the body of the sacral vertebra here described must have belonged to a young Dinosaur of a size far exceeding that of the *Hylæosaurus*. It is obviously very distinct in form from the sacral vertebræ of the *Megalosaurus*. No other reptile than one belonging to the order characterized by the peculiar structure of the sacrum already described, could have yielded a detached vertebral centrum with the remarkable modifications of the one under consideration. The modifications detected in the entire sacrum of the *Iguanodon* in Mr. Saull's collection, justify the reference of the vertebra above described to the sacrum of a young *Iguanodon*.

Caudal Vertebræ.—These are distinguished by the single hæmapophysial surface at each end of the narrow inferior surface of the centrum. The sides of the centrum are flat, or even slightly concave in the vertical direction, though less so than in the antero-posterior direction. In a caudal centrum, for example, in the Mantellian Collection, measuring 4 inches in length, and 5 inches 4 lines in depth at the middle of the side, if a pencil be laid vertically along that part, an interval of between 1 and 2 lines separates its middle part from the bone. Those great Wealden vertebræ which, on the contrary, have the middle of the side of the body prominent, and the lower half only converging towards the under surface, are from the middle and posterior part of the tail of the *Cetiosaurus*. The posterior terminal articular surface is rather more concave than in the dorsal vertebræ; but the difference is by no means so marked as in the plano-concave vertebræ of the *Cetiosaurus*. The transverse processes of the anterior caudal vertebræ are comparatively short, but strong, and are continued from the base of the neurapophysis.

The hæmapophyses, or chevron bones, are not anchylosed to the centrum, but articulate with the interspaces of the vertebræ; in a few of the anterior ones to two distinct but closely approximated surfaces on each contiguous vertebra, but in the rest of the caudal vertebræ to a single oblique triangular surface on each of the contiguous extremities of the centrum; the hæmapophyses being here confluent at their vertebral as well as at their distal extremities.

A caudal vertebra exhibiting this modification in Mr. Holmes's collection measures, in the vertical diameter of the articular surface, 4 inches 9 lines; in its transverse diameter, 4 inches 6 lines; the breadth of the inferior surface of the vertebra is 3 inches 3 lines. The interspace between the anterior and posterior hæmapophysial surface is 9 lines; it is concave in the axis of the vertebra. The diameter of the spinal canal is reduced in this vertebra to 9 lines. The transverse processes are of very small size. The spinous process is broken off. We have seen that those of the sacral vertebræ appear to have been short. There is reason to think that the spinous processes increased in length for a certain distance as they receded from the sacrum, and then diminished. Thus, in a caudal vertebra (No. $\frac{180}{2130}$, Mantellian Collection), evidently anterior in position by its size, by its oblique processes, and by the place of development of its transverse processes from the base of the neural arch, the spinous process is 5 inches in height, while in the six caudal vertebræ preserved in natural sequence and relative position in the Mantellian Collection, the spines are more than double that height. That the vertebra (No. 2130) is not a more posterior caudal vertebra from a larger *Iguanodon* is shown by the relative thickness, as well as position, of its transverse processes, as compared with the six caudal vertebræ above mentioned, for their transverse processes sensibly diminish in every diameter, and especially in vertical thickness, from the first to the sixth; and, moreover, it is evident that, in this short series, the spines decrease in height both forwards from the third as well as backwards, but more so in the latter direction. Thus the spine of the first of these vertebræ is 14 inches high, of the third 15 inches, and of the sixth 13 inches. These spines increase in breadth toward their summits, which are truncated, and in contact with each other, partly from this expansion, partly from the posterior ones being slightly bent forwards. One cannot witness this change of character in so short a segment of the tail without a conviction that this appendage must have been relatively shorter than in the Iguana.

The first spine, besides being somewhat shorter, is more rounded off at its anterior margin than the third, a difference which is still more obvious in the detached caudal above described; but above its origin a thin trenchant plate is extended for a short distance from the middle of the anterior margin: this character, which calls to mind one that is present in a greater proportion of the vertebral column in the Crocodilians, is more strongly developed in the second and third vertebræ. The neurapophysial suture is more nearly obliterated in the sixth than in the first of this instructive series, or in the more anterior and detached caudal vertebra. The following are dimensions of the detached anterior caudal (No. 1), and of the first (No. 2) and last (No. 3) of the series of six:—

	No. 1.		No. 2.		No. 3.	
	In.	Lin.	In.	Lin.	In.	Lin.
Antero-posterior diameter of centrum . . .	2	8	2	8	2	7
Vertical diameter of articular surface . . .	3	6	3	3	2	6
Transverse diameter of articular surface . .	3	5	3	2	2	6
From under part of centrum to upper end of posterior articular process	5	6	5	8	4	0
From upper end of posterior oblique process to the summit of spine	5	0	14	0	10	6
Antero-posterior diameter of base of spine .	1	3*	1	7	1	4
Antero-posterior diameter of summit of spine	2	0	2	2	2	6

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* The anterior basal ridge of this vertebra is broken away.

The transverse processes disappear in the posterior caudal vertebræ. The chevron bones, of which three are preserved in the slab containing the six caudal vertebræ, exhibit the perforated character which distinguishes them from those of the *Cetiosaurus* and of all existing Crocodiles and Lizards, not excepting the Iguana, in which the hæmapophyses are anchylosed at their distal or spinal end only, and remain separate and articulated to two distinct surfaces, at their proximal ends. The length of the superior and inferior vertebral spines, and the shortness of the transverse processes, prove the form of the tail to have been flattened laterally and of great breadth in the vertical direction, at its basal portion at least.

Ribs.—These appendages of the vertebral column are largely developed in the thoracic abdominal region of the spine, and had the same two-fold connexion with the vertebræ as in the other Dinosaurs and the Crocodilians. At the anterior part of the costal region of the spine, the rib was joined by a large head to a shallow cavity, situated at first on the side of the centrum and then on the side of the neurapophysis; and it was further articulated by a tubercle to the extremity of the transverse process. In a certain number of the anterior vertebræ, the neck of the rib was co-extensive with the transverse process, and sometimes six or seven inches in length; afterwards the neck of the rib began to shorten, and the head to decrease in size, and to have its place of articulation brought progressively nearer to the end of the transverse process, until it finally disappeared, and the posterior ribs became appended to the ends of the transverse processes.

In the Iguana, as in other Lizards, the ribs have but one mode of articulation, viz. to a simple tubercle developed from the side of the centrum.

One of the largest double-jointed ribs of the *Iguanodon*, in the Mantellian Collection (No. $\frac{519}{2519}$), is 46 inches in length. The neck is less distinct from the tubercle and body than in other ribs, which seem to have been situated further back; it expands more gradually to the tubercular articulation with the transverse process, and is at this part 5 inches in breadth; it bends with a deep oblique curve for about one-fifth of its length, and then is continued in a nearly straight line to its extremity: this is slightly expanded and truncated, for the attachment doubtless of a bony sternal rib. The convex or outer margin of the rib is bent backwards so as to overhang the sub-compressed shaft of the bone along its upper or proximal third part.

The proximal extremity of one of the ribs from the middle of the trunk of the Horsham *Iguanodon*, presents an ovate head $2\frac{1}{2}$ inches in the long diameter; the neck is 7 inches long, straight, compressed, and topped by a well-marked tubercle, where it joins the body of the rib. This part is also compressed; and its external margin, besides being bent backwards, is also developed in the contrary direction, so as to assume the form of a slightly convex plate of bone 2 inches broad, attached at right angles to the shaft of the rib, which it overhangs on both sides. This structure is characteristic also of some of the ribs in the other Dinosaurs, and is interesting as indicating the commencement of that peculiar development of the corresponding part of the ribs in the Chelonian reptiles, by which the upper part of their bony box is almost wholly formed.

BONES OF THE EXTREMITIES.

Scapular Arch.—The scapula has not hitherto been discovered so associated with other unequivocal portions of the skeleton of the *Iguanodon* as to permit the characters of this bone in that species to be confidently recognised. The bone (No. 194, Omoplate of *Iguanodon*, Mantell. Catal.) agrees with the undoubted scapula of the Hylæosaur, and with that of certain Lacertians, especially of the genus *Scincus**, in the production of a long and slender pointed process, continued at nearly right angles with the body of the bone, from the anterior part of the articular surface for the coracoid; but it differs from the scapula of the Hylæosaur in the presence of two short processes given off from the lower part of the base of the long process, and in the absence of the thick and strong transverse acromial ridge which overarches the glenoid depression, and in the deeper concavity of the posterior margin of the ascending plate or body of the bone. This part, in its shape, relative length and breadth, is intermediate between the Crocodilian and Lacertian type of the scapula, at least as exemplified in the Monitors and Iguanas, where it is broad and short. The Scincs and Chameleons, in the more Crocodilian proportions of their scapulæ, resemble the Hylæosaur and the great species of extinct Saurian, most probably the *Iguanodon*, to which the present bone belongs.

Coracoid.—The thick articular portion of this bone, with its characteristic perforation, here continued to the articular margin by a narrow fissure, dividing the scapular from the humeral articulation, has been found of different sizes in the Tilgate strata, and has been, with much probability, likewise referred to the *Iguanodon*. One of these portions of coracoid, which measured 10 inches in diameter, was found in the same block of stone with other unequivocal remains of *Iguanodon*.

Clavicle.—The doubts which are attached to the determination of the previous parts of the scapular arch are fortunately dissipated from the consideration of this bone by the preservation of both the right and left clavicles in the Maidstone *Iguanodon*. The presence of the fibula in the same block of stone, and its discovery in close proximity with the tibia and femur in the Wealden strata, satisfactorily prove that the present remarkable bone cannot have formed part of the hinder extremity. And since, in other reptiles, the radius differs from the fibula in little more than in being somewhat shorter and thicker, there is still less reason for supposing it to belong to the fore-arm.

The form of the ribs of the *Iguanodon* is well known, and they become shorter and more curved as they advance from the middle to the anterior part of the chest. The determination, therefore, which Dr. Mantell regarded as most probable †, must be held to be the true one. The largest entire clavicle from the Wealden strata measures 29 inches in length, and there is a portion of another in the same collection one-third larger. The largest fibula of the *Iguanodon* that has been found measures 28 inches. The bone is compressed, slender, and subtrihedral at the middle part, expanded and flattened at the two extremities, bent with a slight double curve in a graceful sigmoid form. The broadest end, which, from the analogy of the Cyclodus lizard, must be regarded as the median or pectoral extremity, gives off two processes, the first appearing as a continuation of the thinner margin of the bone, twisted and produced obliquely downwards; the second process is given off nearer the expanded sternal end, towards which it slightly curves.

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* Dr. Mantell has pointed out this resemblance in his Memoir in the Phil. Trans., 1841.

† "If we consider the form of this bone, it appears that the only place it can hold in the skeleton must be either the thorax or lower extremities; it may be a fibula, a rib, or a clavicle; and that it is a clavicle of some extraordinary extinct reptile is certainly most probable."—Geology of the South-east of England, p. 309. The subsequent discovery of the Maidstone *Iguanodon* determined the species of reptile to which the bone in question belonged, and the comparisons mentioned in the text prove it to be a clavicle. The bone attached to the coracoid and omoplate of a small lizard, which I pointed out to Dr. Mantell as resembling the one in question, was the clavicle of the *Cyclodus nigroluteus*. See Dr. Mantell's late Memoir of 1841, Phil. Trans., p. 138.

	In.	Lin.
The breadth of the expanded sternal end of a clavicle, 29 inches in length, is	3	7
The breadth of the scapular end	4	3
From this extremity to the base of the first process	19	0
The breadth of the narrowest part of the shaft	1	7

Humerus.—This important bone has not been hitherto satisfactorily determined; it differs less from the femur in form in Reptiles than in Mammalia. In the Crocodilians it is shorter than the femur, especially in the extinct piscivorous species, with biconcave vertebræ and more strictly aquatic habits. In Lizards it is more nearly equal with the femur, and the similarity of the size of these bones we may conceive to have been greater in the gigantic terrestrial Dinosaurs.

In the modern Crocodiles, the chief distinction in the form of the humerus is the ridge at the upper third of the bone: in Lizards this distinction is almost lost. If we find the femur of the *Iguanodon* distinguished from that of all other reptiles by the presence of a peculiar process from the inner side of the bone, there are not wanting grounds to expect that the humerus may present a similar character.

As the reasons for suspecting that some of the large bones, hitherto uniformly regarded as the femora, may be the humeri of the *Iguanodon*, will best appear in the description of the femur, I shall now proceed to the consideration of the large bones with which the femur is articulated.

Ilium.—The iliac bone of the *Iguanodon* * resembles in form that of the Monitor more than that of the Iguana: in the portion of the pelvis in Mr. Saull's collection it measured 14 inches in length. It commences anteriorly by a thick obtuse extremity slightly bent outwards; this part is supported by the thickest and strongest of the sacral ribs, which slightly inclines backwards: the ilium quickly increases in vertical as well as transverse extent, forming at its lower part the usual portion of the acetabulum; the concavity terminating behind in a broad obtuse prominence: behind this part the ilium rapidly contracts, by a deep inferior emargination, to a comparatively slender process extending backwards and gradually diminishing to an obtuse point, well shown in the detached ilia of the Maidstone *Iguanodon*, but here broken off. The chord of the acetabular arc or concavity, in Mr. Saull's specimen, measured 8 inches.

In the Maidstone *Iguanodon* the left ilium lies detached, with its symphysial articulation or inner surface uppermost, indicating by the extent of that surface, which equals the antero-posterior diameter of nearly five of the dorsal vertebræ of the same individual, the length of the sacrum peculiar to this and other Dinosaurian reptiles. Its slender posterior portion terminates in a subacute point: the anterior extremity of the right ischium, which has the opposite surface exposed, bends slightly outwards in the form of a thick tuberosity.

	In.	Lin.
The length of this bone is	16	0
Its depth	5	0
From the anterior tuberosity to the posterior angle of the acetabulum	8	0

Pubis.—This bone, which presents a simple spatulate form in the Crocodiles, already begins to increase in breadth at its symphysial extremity in the extinct family with concave vertebræ; and in the larger existing species of Lizards is expanded at both extremities, and has a very marked and recognizable character superadded, in being bent outwards with a considerable curvature.

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* This bone is figured in Dr. Mantell's Memoir, Phil. Trans. 1841, pl. viii. fig. 28.

A massive fragment of a broad osseous plate, bearing a segment of a large articular cavity at its thickest margin, and thence extended as a thinner plate, bent with a bold curvature, and terminated by a thick rounded labrum, offers characters of the Lacertian type of the pubis too obvious to be mistaken. This specimen is from the Tilgate strata; and, since the modifications of the ilium of the *Iguanodon* in the Maidstone skeleton approximate to the Lacertian type of the bone, and especially as manifested by the great *Varani*, in which the recurved character of the pubic plate is most strongly marked, we may, with much probability, assign the fossil in question to the pelvis of the *Iguanodon*.

This fine portion of pubis is of an inequilateral triangular form, 16 inches in its longest diameter, 9 inches 6 lines across its base or broadest part, 6 inches 8 lines across its narrowest part. The fractured surface of the bone, near the acetabulum, is 3 inches 3 lines thick. The acetabular depression is 7 inches across, a proportion which corresponds with that of the acetabular concavity in the ilium, and with the size of the cavity in which the head of the Iguanodon's femur must have been received. One angle of the cavity, corresponding with the anterior one in the *Varanus*, is raised; a broad and low obtuse ridge bounds the rest of the free margin of the cavity. The smooth labrum exchanges its character near one of the fractured edges of the bone for a rough surface, which indicates the commencement of the symphysis. In the apparent absence of the perforation below the acetabular depression, the present bone agrees with the Crocodilian type.

Ischium.—A second fragment of a large lamelliform bone (No. $\frac{188}{2188}$, Mantellian Catalogue) presents, in its general form and slightly twisted character, most resemblance to the ischium, with traceable modifications intermediate to those presented by the extinct *Goniopholis* and modern *Varani* and *Iguanæ*. The loss of the acetabular extremity, which is broken away, prevents a certain determination of this bone; the only natural dimension that can be taken is the circumference of the neck, or contracted portion between the acetabular end and the expanded symphysial plate: this circumference gives 7 inches. The slight twist of the bone upon this part as it expands to form the broad symphysial plate,—a character which is well marked in the ischium of the *Goniopholis*,—gives it a superficial resemblance to the humerus of some of the large Mammalia; but the bone is too short in proportion to the breadth indicated by the fractured symphysial end, to afford a probability of its having been the humerus of a land reptile, and much less of the *Iguanodon*, in which the form of the femur is well ascertained; unless, indeed, there be actually more discrepancy between the femur and humerus in size and form in the Dinosaurs, than has, hitherto, been recognized in the Reptilian Class.

Femur.—The Maidstone *Iguanodon* does not satisfactorily determine the question of the principal bone of the fore and hind extremities, for whilst the clavicles, many anterior dorsal vertebræ and anterior ribs, would lead one to suppose that the two long bones found in their proximity might be humeri; on the other hand the presence of the iliac bones, with some caudal vertebræ in the same slab, give equal probability to their being femora. The bones in question (1 and 2 in the figure of the Maidstone *Iguanodon*, published by Dr. Mantell in his 'Wonders of Geology,' vol. i. pl. ii.) have the same general characters, viz. the flattened trochanter at the proximal end, the compressed ridge-like process at the middle, and the two condyles with the deep and narrow fissure at the distal end, which are presented by the larger detached bones, described by Dr. Mantell as femora, from the Tilgate strata. They are otherwise too much crushed and buried to yield materials for more minute comparison: each of these bones measures 33 inches in length.

In five separate long bones, having the general characters of the two abovementioned in the Maidstone *Iguanodon*, numbered consecutively and marked 'Femur' in the Mantellian Collection, Nos. 1 and 3 differ from Nos. 4 and 5 in the greater inward production of the head, making the concavity of the line descending from the head to the median internal ridge somewhat deeper. The lower angle of this median ridge is more produced in Nos. 1, 2 and 3, than in Nos. 4 and 5. The whole inner contour is more regularly concave in No. 5, than in Nos. 1 or 3. Of these five bones, No. 2 was found associated with a tibia and fibula; and if, therefore, the differences above indicated should be more than mere individual varieties of the same bone, we might conclude Nos. 4 and 5 to be humeri. Such conclusion appears more probable from the circumstance of two of the longest and largest of the bones, having the general characters of the femur of the *Iguanodon*, which were obtained by Mr. Holmes from the quarry of the Wealden stone at Horsham, belonging both to the right side.

Now the other bones obtained in proximity with the above were all parts of one large individual, and it is much more probable, therefore, that we have here a right humerus and femur of the same individual, than two right femora of different individuals. One of the differences noticed in the Tilgate specimens, viz. the degree of obliquity at which the neck joins the shaft, is discernible in these; and close to that bone, which shows the characters that we have supposed to belong to the femur, were found bones corresponding with the tibia and fibula.

Regarding then this as the femur, it presents the following characters:—it measures 3 feet in length: its circumference at the middle of the shaft is 18 inches: the contour of the rounded inward-projecting part of head is 17½ inches: two flat longitudinal facets meet near the middle of the anterior surface of the shaft at a rough and slightly elevated angle, which runs straight down to within thirteen inches of the distal end: the ridge there inclines towards the internal condyle and subsides. Two strong *vasti internus et externus* muscles are indicated by this ridge. The head of the bone is carried inwards, overhanging the shaft in a greater degree than the corresponding part does in the humerus. The line of the inner side of the shaft describes a graceful sinuous curve, being first concave, then slightly convex at the middle, where there is an indication of the projecting ridge which has been broken off: below this it is concave to the flattened antero-posteriorly extended, slightly concave surface, which descends vertically to the articular surface of the condyle, which surface proceeds horizontally at nearly a right angle with the line of the shaft of the bone. The antero-posterior extent of the flattened condyle is 8 inches. The thickness of the external wall of the shaft varies from half an inch to an inch.

Both ends of this fine bone are crushed and mutilated.

By the side of the femur were found two other bones, the largest of which corresponds with the tibia. The external part of the head is considerably produced horizontally; the circumference of the proximal articular surface is 30 inches. The longitudinally finely striated vertical surface of the shaft of the bone commences at the anterior part of the proximal end along a well-defined curved line, which runs transversely across the bone, convex downwards in the middle and concave downwards at each end: the bone rapidly contracts, and assumes, about 8 inches below the head, the subquadrilateral form; it is broadest from side to side: its circumference is here 15 inches. The anterior surface is flattened; the outer or radial side convex or rounded: the dense external walls of this bone are very thick, at least 1 inch. The length of this bone is 27 inches, but it wants the distal end. The proximal articulation is very convex from behind forwards, but, at the middle, it is slightly concave from side to side.

	In.	Lines.
Its lateral diameter is	12	0
Its antero-posterior diameter is	5	6

The disparity of size between the tibia and fibula is considerable, but the disparity in the thickness of the two extremities of the bone is less than in the bone which is described and figured as the fibula by Dr. Mantell. On the middle of one of the flat sides of the fibula is an oblong rough surface slightly raised, measuring 3 inches by 2 inches. The articular extremities of the fibula are tuberculate; the larger end is 4 inches across, the smaller one 3 inches across. The shaft is subcompressed.

A few yards from the three preceding bones was found the, presumed, humerus, which measured 35 inches in length, being very nearly equal in size with the femur. Its proximal extremity is crushed and mutilated: the shaft is compressed from before backwards; concave behind: the submedian ridge or compressed process is developed from the inner side of the shaft at the usual situation, and corresponds in form with those of the bones Nos. 4 and 5, Mantellian Collection. The distal condyles are divided anteriorly by a narrow longitudinal furrow, which penetrates deeply between them. As the absence of the deep fissure between the condyles of the femur is repeated in the humerus of the Iguana, so may its presence be repeated in the humerus of the *Iguanodon*.

The inner condyle projects backwards beyond the outer one, which is distinguished by being traversed by a longitudinal groove. This bone differs from the femur in the shorter neck supporting the head, in its more prominent median process, and in the uniform though slight concavity of the inner margin of the shaft.

The preceding observations were made during an inspection of the fossils in Mr. Holmes's interesting collection in the summer of 1840. I have subsequently been favoured by a letter from that gentleman, containing the following clear and valuable observations on the two large bones in his collection, which support the view I had taken of their nature.

"I have also examined the two large bones concerning which so much doubt exists. They both appear to belong to right extremities, but as the one which has the trochanter, and which by way of distinction I shall call No. 1 (humerus?), is so much crushed in the direction of the rough ridge, so strongly marked in the other, I cannot say with any degree of certainty whether it possessed the same form or not. There is, however, this difference at any rate. The head of No. 1 is so much mutilated that little can be said about it, but it is very clear that the neck is shorter than that of No. 2 (femur?), and there is a variation of nearly one-half in the degree of obliquity from the perpendicular of the shaft of the bone in which the two heads are set on; that of No. 2 being more so than the other. They also differ in another respect. In measuring from the inferior part of the head, supposing both bones to be placed in an erect position, to the superior portion of the condyle, which is the best way in which I can ascertain their relative length; No. 2 is longer in the shaft than the other bones, which, if they both belonged to the same individual, (and I think there is no sufficient reason to doubt it) would, according to thy conjecture, make it appear that one is the femur and the other the humerus.

"The question next arises as to which of the bones either name is to be appropriated. No. 1 has the trochanter, which is very similar in shape to the femur marked No. 5 in the British Museum. No. 2 has none in its present mutilated state, but on examining the posterior part of the shaft, where on the internal side one might expect to meet with some remains of the base of the trochanter, I find the surface of the bone concave, and it diverges much more than I should suppose it would do if it had merely been continuous with the returning surface from the anterior part of the bone, if there had been no trochanter interposed to disturb the otherwise greater rotundity of the shape.

"This leads me to suppose that it once had one, and that it probably might have been formed like that in Nos. 1 and 2 in the British Museum. If they were not the bones of distinct animals, this might perhaps have been the case." Dated Horsham, Nov. 2nd, 1841.

The characters of the articular extremities of the femur which are obscured by the mutilated condition of the large specimen, are beautifully shown in the femur of a young *Iguanodon*, obtained from a pit near Rusper, four miles north of Horsham. The rounded portion of the head extends inwards; it is indented at its anterior part by the commencement of a longitudinal broad channel, which extends down upon the shaft: the articular surface is not confined to the inwardly produced head, but extends over the whole proximal horizontal surface of the femur, expanding as it approaches the outer part of the head. The articular surface is circumscribed by a well-defined linear groove, which separates it from the longitudinal striated surface of the shaft of the bone. At the posterior and external angle of the articular proximal end of the bone, a longitudinal column, separated by a longitudinal groove from the main shaft of the bone, falls into that shaft a little lower down the distal end: here the shaft expands and becomes flattened from before backwards. The distal end is characterized by a deep and narrow anterior longitudinal groove, situated not quite in the middle, but nearer the internal condyle: there is a corresponding longitudinal groove on the posterior part of the distal end, which is wider than the anterior one, and in the middle of the bone, separating the two condyles, but inclining beneath, and, as it were, undermining the backward projecting part of the internal condyle; this is much more prominent than the external one, which is traversed or divided by a narrow longitudinal fissure. The articular surface is irregular and tuberculate.

	In.	Lines.
The lateral diameter of proximal end	2	8
The lateral diameter of distal end	3	0
Antero-posterior diameter of outer part of proximal end .	2	0
Antero-posterior diameter of outer part of internal condyle	2	3

The femur of the Iguana differs as widely from that of the *Iguanodon* as does that of the Monitor or any other Lacertian reptile. The forms of the head and trochanter of the femur of the Iguana are just the reverse of those in the *Iguanodon*. The head of the femur in the Iguana is flattened from side to side, and its upper convex surface is extended from before backwards, making no projection over the gentle concave line leading from its inner surface down to the inner condyle. In the *Iguanodon* the head is rounded and rather compressed from before backwards; and is produced, as in Mammals, over the inner side of the shaft.

In the Iguana the trochanter is compressed from before backwards, and is separated by a wide and shallow groove from the oppositely compressed head: in the *Iguanodon* the trochanter is singularly flattened from side to side, and is applied to the outer side of the thick neck, from which it is separated by a deep and narrow fissure. The Iguana has no submedian internal process, and its distal condyles are slightly divided by a shallow depression.

The circumference of the femur of the *Iguanodon* very nearly equals one-half its length: the circumference of the femur of the Iguana only equals one-fourth its length: yet the femur of the *Iguanodon* equals the united length of eleven of its dorsal vertebræ, while that of the Iguana equals the united length of only six of its dorsal vertebræ.

The femora of the Iguana stand out, like those of most other Lacertians, at right angles with the vertical plane of the trunk, which is rather slung upon than supported by those bones: but it is evident from the superior relative length and strength of those bones in the *Iguanodon*, from the different conformation of the articular, especially the proximal extremities, and from the ridges and processes indicative of the powerful muscles inserted into the bone, that it must have sustained the weight of the body in a manner more nearly resembling that in the pachydermal Mammalia. As in some of the more bulky of these quadrupeds, the indication of the 'ligamentum teres' is wanting in the head of the femur of the *Iguanodon*.

The tibia of the *Iguanodon* equals the united length of nine of the dorsal vertebræ, while in the Iguana it does not exceed the united length of five dorsal vertebræ, although it more nearly equals the femur in length than in the *Iguanodon*. The head of the tibia is more expanded and complicated by deep and wide grooves in the *Iguanodon*: the fibula is less expanded towards the distal end and less flattened against the tibia in the *Iguanodon*.

The fibula of the small *Iguanodon* from the pit at Rusper, equals the antero-posterior extent of the spines of eight dorsal vertebræ of the same individual. This bone is 13 inches long, 2 inches across the proximal end, and 6 lines across the distal end.

Of the great *Iguanodon* from the Horsham quarry two metacarpal or metatarsal bones are preserved in natural juxtaposition: one exceeds the other by four inches, and measures 2 feet 6 inches; the breadth of its distal end is 3 inches 3 lines; the shaft is compressed and subtrihedral; its texture is spongy at the centre. The proximal end is expanded, with a nearly flat articular surface, the contour of which is broken by two longitudinal indentations: the distal end offers a well-sculptured trochlear articulation for the first phalanx. The bone of the Maidstone *Iguanodon* (marked 7 in the figure above cited in the 'Wonders of Geology') corresponds with the above described bones of the foot.

Some of the phalanges, probably the middle ones, appear to have been singularly abbreviated; but they have not yet been discovered in such juxtaposition with undoubted Iguanodon's bones as to justify a more precise description of their characters under the present head.

The distal or ungual phalanges of the *Iguanodon*, although doubtless offering certain modifications of form in different toes, are shown by those preserved in the Maidstone *Iguanodon*, and others of much larger dimensions, found associated with the bones of the great *Iguanodon* of the Horsham quarry, to have had a less incurved, broader and more depressed form than in other known Saurians. Two of the largest ungual phalanges of the Horsham *Iguanodon* in Mr. Holmes's collection, are broad, subdepressed, with the curved vascular groove on each side, as in most other Saurians, with a slightly concave articular base, and terminating forwards in a round blunt edge; the outer boundary of the lateral grooves forms, at the posterior end of the groove, a laterally projecting process, rendering this part of the phalanx broader than the articular extremity or basis. The following are dimensions of the largest of the two phalanges:—

	In.	Lines.
Length	5	4
Breadth	3	2
Breadth at articular end	3	0
Depth at articular end	2	3

The last dimension gradually diminishes to the distal end.

This phalanx is slightly bent downwards; the under surface being concave longitudinally, but convex from side to side; less so than on the upper surface. The under surface is rough; the upper surface nearly smooth, except at the margin of the articular surface, on the projecting sides and at the distal extremity, which is sculptured by irregular vascular grooves and holes. The phalanx has a slight oblique twist to one side, and is somewhat thinned off to that side on which the curved groove is longer than on the other side.

In Mr. Saull's museum is an ungual phalanx of an *Iguanodon*, which nearly equals those from Horsham, and presents the same subdepressed form. The base is slightly convex transversely; more concave vertically: the articular surface is faintly divided by a median vertical rising: the rounded edge of the articular surface is slightly raised, interrupted on both sides by the smooth shallow commencement of the curved vascular groove: this deepens and contracts as it extends forwards. The upper surface is convex longitudinally and transversely; the lower surface is rather more convex transversely than the upper, but is slightly concave longitudinally. The upper and lateral surfaces, for about an inch near the base, are deeply sculptured by large irregular longitudinal grooves and ridges; the rest of the upper surface is impressed by fine interrupted longitudinal impressions; but having, on the whole, a smooth appearance. The laminated superposition of the exterior compact portion of the bone is shown by the separation of portions of the layers of about one line in thickness. The under surface is more deeply impressed by cavities having reticulate elevations. The right aliform process begins 10 lines from the articular surface, the left about 14 lines from the same part: their base is bounded below by slight impressions, and above by the lateral canals, which appear to sink into the bone. A few distant vascular grooves mark the upper surface of the bone, but more numerous larger ones are situated near the lateral canals and at the broken anterior end of the phalanx. The following are the dimensions of this bone:—

	In.	Lines.
Transverse diameter	3	5
Transverse diameter of broken end	2	2
Vertical diameter of base	2	7
Vertical diameter of broken end	1	6
Length to broken end	4	4

it was probably more than 5 inches long when entire.

The largest of the phalangeal bones in the collection of Wealden Reptiles in the British Museum, which from its breadth, slight degree of obliquity and vascular canals is referrible to the *Iguanodon*, is less than those just described. The phalanx in question (No. $\frac{384}{2381}$, Mantellian Collection) is conical, 4½ inches long, probably 5 inches when entire; but the apex is broken off: the longest diameter of the base or articular surface is 3 inches 3 lines: it is slightly and obliquely compressed, and very slightly curved, and from this circumstance, as well as from the obliquity of the base and its unsymmetrical figure, it probably belonged to the small outer or inner toe at the margin of the foot. Only a small part of the natural smooth articular surface is left, the rest appears to have been scraped away, so that the coarse cancellous structure of the middle of the bone is exposed. The free surface of the bone near the base is deeply sculptured by irregular longitudinal furrows, which served for the implantation of the articular ligaments. The rest of the free surface is tolerably smooth, except at the sides near the apex, where there are numerous oblique outlets for the large vessels and nerves supplying the secreting organ of the claw. The two lateral longitudinal curved grooves which characterize the claws of most Saurians are here well developed; they commence, one at, the other near, the base; are at first shallow, then deepen, and finally sink into the substance of the bone about 1½ inch from its fractured apex. Below one of these canals there is a shallow smooth impression, corresponding no doubt with the margin of the claw. The under surface of the phalanx indicated by the concavity of the curved grooves is more convex transversely than the upper surface: the distance between the converging lateral grooves in this surface is one inch.

Among the few other phalangeal bones from Dr. Mantell's collection in the British Museum, there is one (figured in the 'Wonders of Geology,' pl. iii. fig. 1, as belonging to the fore-foot of the *Iguanodon*) which differs in a marked manner from the specimens just described, being as much compressed from side to side as the Iguanodon's ungual phalanges are, for the most part, flattened from above downwards. One of these compressed phalanges must have been at least four inches in length; it now measures three inches, with the extremity broken off; it is 2 inches 8 lines in vertical diameter at the base, and only 1 inch 2 lines in the greatest transverse diameter. The phalanx is more curved downwards than any of the true Iguanodon's phalanges, and it is traversed by a longer and shallower groove, the lower margin of which is not produced into a lateral aliform process, nor does the distal end of the groove sink into the substance of the bone.

The ungual phalanges on both the fore and hind feet of the Iguana resemble this phalanx in form more than they do those of the *Iguanodon*. In the fore-foot of the Crocodile the ungual phalanx of the first or innermost toe is broad and flat, with lateral ridges, much resembling the depressed phalanges of the *Iguanodon*. The ungual phalanx of the third digit is of the same length, but is thinner in both transverse and vertical directions, but is less so in the latter. It is not more curved. Still the difference (and this is the greatest that I can perceive in comparing the different ungual phalanges of the same individual Crocodile (*Croc. acutus*)) is much less than that which is manifested between the depressed and the compressed phalanges hitherto referred to the *Iguanodon*. In the great proportion of the skeleton found near Maidstone are two phalanges which correspond in form with those enormous specimens found near Horsham, and with the small depressed claw-bones from Tilgate Forest, unquestionably belonging to the *Iguanodon*, and supposed by Dr. Mantell to be peculiar to the hind-foot of that Saurian.

Size of the Iguanodon.—From the comparison, which the few connected portions of the skeleton of the *Iguanodon* enable us to make, between the bones of the extremities and the vertebral column, it is evident that the hind-legs at least, and probably also the fore-legs, were longer and stronger in proportion to the trunk than in any existing Saurian. One can scarcely suppress a feeling of surprise, that this striking characteristic of the *Iguanodon*, in common with other *Dinosauria*, should have been, hitherto, overlooked; since the required evidence is only an associated vertebra and long bone of the same individual, or a comparison of the largest detached vertebræ with the longest femora or humeri. This characteristic is, nevertheless, one of the most important towards a restoration of the extinct reptile, since an approximation to a true conception of the size of the entire animal could only be made after the general proportions of the body to the extremities had been ascertained.

But it is very obvious that the exaggerated resemblances of the *Iguanodon* to the Iguana have misled the Palæontologists who have hitherto published the results of their calculations of the size of the *Iguanodon*; and, hence, the dimensions of 100 feet in length arrived at by a comparison of the teeth and clavicle of the *Iguanodon* with the *Iguana*, of 75 feet from a similar comparison of their femora, and of 80 feet from that of the claw-bone, which, if founded upon the largest specimen from Horsham, instead of the one compared by Dr. Mantell*, would yield a result of upwards of 200 feet for the total length of the *Iguanodon*, since the Horsham phalanx exceeds the size of the largest of the recent Iguana's phalanges by 40 times!

But the same reasons which have been assigned for calculating the bulk of the *Megalosaurus* on the basis of the vertebræ, apply with equal force to the *Iguanodon*. Now the largest vertebra of an *Iguanodon* which has yet been obtained does not, as has been before stated, exceed 4½ inches in length; the most common size being 4 inches. The intervertebral substance is shown, by the naturally juxtaposed series of dorsal vertebræ in the Maidstone *Iguanodon*, to be not more than one-third of an inch in thickness. All the accurately determined vertebræ of the *Iguanodon* manifest the same constancy of their antero-posterior diameter which prevails in Saurians generally; the discovery of the true character of the supposed Lacertian vertebræ, six inches in length, removes the only remaining doubt that could have attached itself to this important element in the present calculation†. The cervical vertebræ of the *Iguanodon*, when discovered, if they prove to differ in length from the known dorsal and caudal vertebræ, will be, in all probability, somewhat shorter, as they are in the Hylæosaur and in all known Crocodiles and Lizards. It remains, therefore, to discover the most probable number of the vertebræ of the *Iguanodon*, in order to apply their length individually to the estimate of the length of the entire body. The structure of the vertebræ and the ribs, and especially the variation in both structure and size which the ribs of the *Iguanodon*, already obtained, demonstrate to have prevailed in the costal series, render it much more probable that the number of the costal vertebræ would resemble that of the Crocodiles than that of the *Scincus* or other Lizards with unusually numerous dorsal vertebræ, and which possess ribs of a simple and uniform structure, and of nearly equal size. The most probable number of vertebræ of the trunk, from the atlas to the last lumbar inclusive, calculated from Crocodilian analogies, would be 24 vertebræ; which is also the number possessed by the Iguana.

Twenty-four vertebræ, estimated with their intervertebral spaces at 5 inches each, give 10 feet; if to this we add the length of the sacrum, viz. 17 inches, then that of the trunk of the *Iguanodon* would be 11 feet 5 inches; which exceeds that of the Megatherium. If there be any part of the skeleton of the Iguana which may with greater probability than the rest be supposed to have the proportions of the corresponding part of the *Iguanodon*, it is the lower jaw, by virtue of the analogy of the teeth and the substances they are adapted to prepare for digestion. Now the lower jaw gives the length of the head in the Iguana, and this equals the length of six dorsal vertebræ, so that as 5 inches rather exceeds the length of the largest Iguanodon's vertebra yet obtained, with the intervertebral space superadded, on this calculation the length of the head of the largest *Iguanodon* must have been 2 feet 6 inches. In the description of the caudal vertebræ it has been shown that the *Iguanodon* could as little have resembled the Iguana in the length of its tail‡, as in the anatomical characters of any of the constituent vertebræ of that part: the changes which the series of six caudal vertebræ present in the length and form of the spinous processes, and in the place of origin of the transverse processes, indicate the tail to have been shorter in the *Iguanodon* than in the Crocodile. Assuming, however, that the number of caudal vertebræ of the *Iguanodon* equalled that in the Crocodile, and allowing to each vertebra with its intervertebral space 4½ inches, we obtain the length of 12 feet 6 inches for the tail of the *Iguanodon*. On the foregoing data, therefore, we may liberally assign the following dimensions to the *Iguanodon* :—

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* Mantell, Geology of the South-east of England, p. 314.

† See p. 92 of the present Report.

‡ See also the judicious remarks by Dr. Buckland to the same effect, Bridgewater Treatise, p. 244.

	Feet.
Length of head, say	3
Length of trunk with sacrum	12
Length of tail	13
Total length of the *Iguanodon*	28

The same observations on the general form and proportions of the animal, and its approximation in this respect to the Mammalia, especially the great extinct Megatherioid or Pachydermal species, apply as well to the *Iguanodon* as to the *Megalosaurus*.

Order LACERTILIA.

Leaving now the gigantic Saurians constituting the order *Dinosauria*, above characterized, and establishing in several important points of their osteological structure the transition from the Crocodilian to the Lacertian order, I next proceed to notice the remains of those extinct Reptiles, which manifest in the enduring parts of their organization a closer affinity to the extensive and varied order of the smaller and lower organized Saurians which are distributed over all the warmer parts of the present surface of the earth.

The ancient representatives of the Lacertian order are for the most part of gigantic size, and deviate, like many of the ancient Crocodilians, from existing Lizards, by very remarkable characters of the vertebræ, teeth, and dermal bones.

Genus MOSASAURUS.

Commencing with the species which retain the ordinary ball and socket structure of the vertebræ, the gigantic *Mosasaurus* first claims attention. Two vertebræ which have the anterior articular facet concave, the posterior convex, and the other characters of this genus, are preserved in the Mantellian Collection. They are from the chalk formation in Sussex, and have been referred by Dr. Mantell to the genus *Mosasaurus*.

Genus LEIODON.

Hitherto no teeth corresponding with those of the *Mosasaurus Hoffmanni* of St. Peter's Mount near Maestricht, have been discovered in the chalk formations of England. The teeth of the Pliosaur have, in some instances, been mistaken for those of the Mosasaur.

The teeth from the chalk of Norfolk, figured and described in my 'Odontography*' as representatives of the genus *Leiodon*, make the nearest approach to the characters of those of the *Mosasaurus*. They are about one half the size of the maxillary teeth of the *Mosasaurus Hoffmanni*, and differ more essentially in having their outer side as convex as the inner side, the transverse section of the crown being elliptic, the pointed extremities of the ellipse corresponding with two opposite longitudinal trenchant ridges, which separate the outer from the inner side of the tooth. The crown expands at the base, which is circular, and is anchylosed to a conical process, developed from the broad alveolar margin of the jaw. In this, which is termed the "acrodont" type of dentition, the *Leiodon* corresponds with the *Mosasaur*. It is probable that the vertebræ of the two extinct reptiles may have corresponded in form; and it is possible that those from the English chalk, hitherto referred to the *Mosasaurus*, may appertain to the same species as the teeth here described. From the correspondence in the general structure, smooth external surface, and mode of attachment of the teeth between the Maestricht Mosasaur and the English Leiodon, it may be concluded that the latter reptile had the same affinity to the Lacertian type, which the Mosasaur so strikingly manifests in the presence of pterygoid teeth.

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* P. 261, pl. lxxii.

Genus RAPHIOSAURUS.

Under this name I propose to notice a small and hitherto undescribed genus of Lacertians, from the chalk formations near Cambridge, indicated by a portion of the lower jaw, containing twenty-two close-set, awl-shaped teeth anchylosed by their bases to an outer alveolar parapet of bone, and thus corresponding with the pleurodont type of dentition among the Lizards.

To the same genus may belong a beautiful specimen in the museum of Sir Philip Egerton, consisting of a series of twenty dorsal, two lumbar, two sacral, and a few of the caudal vertebræ, with the pelvic bones, from the chalk near Maidstone, which correspond with the jaw of the *Raphiosaurus* in size. The vertebral characters are essentially those of the modern Lacertians; but the absence of extremities and teeth prevents the generic affinities being accurately determined.

It is interesting to find this second instance of the 'procœlian' type of vertebræ—or those with the anterior cup and posterior ball—in the chalk formations, below which I have not met with any instance of a Reptile agreeing with the existing species in this structure.

Pleurodont Eocene Lizard.—Among the fossils obtained by Mr. Colchester from the Eocene sand, underlying the Red Crag at Kyson, or Kingston, in Suffolk, the existence of a lizard, about the size of the Iguana, is indicated by a part of a lower jaw, armed with close-set, slender, subcylindrical, antero-posteriorly compressed teeth, attached to shallow alveoli, and with their bases protected by an external parapet of bone. The fragment of jaw is traversed by a longitudinal groove on the inside, and perforated, as in most modern lizards, by numerous vascular foramina along the outside. The teeth are hollow at their base.

Scincoid Oolite Lizard.—A small Lacertian is indicated by remains discovered in the celebrated oolite at Stonesfield. The most intelligible of these is a femur, ten lines in length, having a hemispherical head supported on a short subcompressed neck, on each side of the base of which there is a strong conical trochanterian process: the middle of the shaft is cylindrical, and soon expands to form a broad distal extremity. This shape of the bone proves it not to be the young of any of the great Saurians hitherto discovered at Stonesfield (the expansion of the distal end removes it from the Chelonian reptiles), but indicates its affinity to the Scincoidian lizards, the largest forms of which, it may be remarked, now exist in Australia, where they are associated with *Araucariæ* and cycadeous plants, with living *Terebratulæ*, and *Trigoniæ*, and with the peculiar marsupial quadrupeds; the remains of all which forms of organized beings characterize the same stratum and locality as that in which the present extinct Lacertian was found.

No vertebræ of the procœlian type have hitherto been discovered in the oolite, and it is most probable that those of the small Lacertian here indicated, agree with those of most other extinct Saurians of the secondary formations in having both articular extremities subconcave.

Genus RHYNCHOSAURUS.

The biconcave structure unquestionably characterizes the vertebræ of the small Lacertian from the new red sandstone quarries near Shrewsbury, on which the well-marked and distinct genus *Rhynchosaurus* is founded.

For the opportunity of examining the rare and interesting remains of the *Rhynchosaurus* I am indebted to Dr. Ogier Ward of Shrewsbury, and to the Council of the Natural History Society of that town, in the museum of which many of the fossils here described are deposited.

They occur at the Grinsill quarries, in a fine-grained sandstone, and also in a coarse burr-sandstone; in the latter are imbedded some vertebræ, portions of the lower jaw, a nearly entire skull, fragments of the pelvis and of two femora: in the fine-grained sandstone, vertebræ, ribs, and some bones of the scapular and pelvic arches are imbedded. The bones present a very brittle and compact texture; the exposed surface is usually smooth, or very finely striated, and of a light blue colour. The sandstones containing these bones occasionally exhibit impressions of footsteps which resemble those figured in the Memoir by Messrs. Murchison and Strickland, Geol. Trans., 2nd Series, vol. v. pl. xxviii. fig. 1, but differ in the more distinct marks of the claws, the less distinct impression of a web, the more diminutive size of the innermost toe, and an impression corresponding with the hinder part of the foot, which Dr. Ward compares to "a hind-toe pointing backwards, that, like the hind-claw of some birds, only touched the ground with its point, which was armed in some of the foot-prints with a claw still longer than those of the fore-toes *." The foot-prints are likewise more equal in size and likewise in their intervals than those figured by Messrs. Murchison and Strickland: they measure from the extremity of the outermost or fifth toe to that of the innermost or first rudimental toe, about one inch and a half. They are the only foot-prints that have as yet been detected in the new red sandstone quarries at Grinsill.

I proceed now to describe the fossil bones, respecting which Dr. Ward observes, "as they have always been found nearly in the same bed as that impressed by the footsteps above described, I am induced to believe that these are the bones of the same animal:" an opinion, which, from the correspondence between the bones and the foot-prints in size, is, at least, highly probable.

Vertebræ.—Both surfaces of the centrum are concave, and are deeper than in the biconcave vertebræ of the extinct Crocodilians; the texture of the centrum is compact throughout. The two lateral surfaces join the under surface at a nearly right angle, the transverse section presenting a subquadrate form, with the angles rounded off: the under surface and sides are regularly concave longitudinally.

The neural arch is anchylosed with the centrum, without trace of suture, as in most lizards: it immediately expands and sends outwards from each angle of its base a broad triangular process with a flat articular surface; the two anterior surfaces look directly upwards, the posterior ones downwards; the latter are continued backwards beyond the posterior extremity of the centrum; the tubercle for the simple articulation of the rib is situated immediately beneath the anterior oblique process. So far the vertebræ of the *Rhynchosaurus*, always excepting their biconcave structure, resemble the vertebræ of most recent lizards. In the modification next to be noticed, they show one of the vertebral characters of the *Dinosauria*. A broad obtuse ridge rises from the upper convex surface of the posterior articular process and arches forwards along the neural arch above the anterior articular process, and gradually subsides anterior to its base: the upper part of this arched angular ridge forms, with that of the opposite side, a platform, from the middle line of which the spinous process is developed. This structure is not present in existing lizards; the sides of the neural arch in their vertebræ immediately converge from the articular processes to the base of the spine, without the intervention of an angular ridge formed by the side of a raised platform. The base of the spinous process in the Rhynchosaur is broadest behind, and commences there by two roots or ridges, one from the upper and back part of each posterior articular process: they meet at the posterior part of the summit of the neural arch, whence the spinous process is continued upwards as a simple plate of bone, its base extending forwards along about two-thirds of the length of the platform, which then again divides into two ridges, which diverge from each other in slight curves to the anterior and external angles of the neurapophyses. The interspace of the diverging anterior crura of the base of the spine is occupied by a triangular fossa, not continued into the substance of the spine; this fossa is bounded below by a horizontal plate of bone extended over the anterior part of the spinal canal, and terminated by a convex outline. The anterior margin of the spinous process is thin and trenchant; the height of the spine does not exceed the antero-posterior diameter of its base; it is obliquely rounded off. The spinal canal sinks into the middle part of the centrum and rises to the base of the spine, so that its vertical diameter is twice as great at the middle as at the two extremities: this modification resembles in a certain degree that of the vertebræ of the *Palæosaurus* from the Bristol conglomerate. The following are dimensions of the most perfect of the dorsal vertebræ of the *Rhynchosaurus*:—

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* Extract of a letter, dated Shrewsbury, November 27th, 1840.

	Lines.
The length of the centrum	5½
Height of the articular end	3
Breadth of the articular end	2⅔ ⅓
From the lower margin of the posterior extremity of the centrum to the posterior part of the base of the spine	5
From the lower margin of the posterior extremity of the centrum to the summit of the spine	9
Antero-posterior extent of base of spine	4
Breadth of the neural arch, from the outer margin of one anterior articular process to that of the opposite side	8½
Breadth of the neural arch at the interspace between the anterior and posterior oblique processes	4
Breadth of the neural arch across the middle of the spinal platform	2

Skull.—The most complete specimen yet obtained of this instructive part of the skeleton of the *Rhynchosaurus*, is imbedded in a portion of the coarse-grained sandstone from the Grinsill quarries. The lower jaw is in its natural position, as when the mouth is shut, showing that the parts had not been dislocated from the time of the death of the animal to its becoming imbedded in the sand.

The skull presents the form of a four-sided pyramid, compressed laterally, and with the upper facet arching down in a graceful curve to the apex, which is formed by the termination of the muzzle. The very narrow cranial box; the wide temporal fossæ on each side, bounded posteriorly by the parietal and the mastoid bones, and laterally by strong compressed zygomata; the long tympanic pedicle, descending freely and vertically from the point of union of the posterior transverse and zygomatic arches, and terminating in a convex pulley for the articular concavity of the lower jaw; the large and complete orbits; and the short, compressed, and bent down maxillæ,—all combine to prove the fossil to belong to the Lacertian division of the Saurian order. The mode of articulation of the skull with the spine cannot be determined in the present specimen, but the lateral compression and the depth of the skull, the great vertical breadth of the superior maxillary bone, the smaller relative size of the temporal spaces, the great vertical breadth of the lower jaw, all prove that it does not belong to a reptile of the Batrachian order. The shortness of the muzzle and its compressed form, equally remove it from the Crocodilians. No Chelonian has the tympanic pedicle so long, so narrow, or so freely suspended to the posterior and lateral angles of the cranium.

The general aspect of the skull differs, however, from that of existing Lacertians, and resembles that of a bird or turtle, which resemblance is increased by the apparent absence of teeth. The intermaxillary bones, moreover, are double, as in Crocodiles and Chelonians, but, with this exception, all the essential characters of the structure of the skull are those of the Lizard.

Of the proper walls of the cerebral cavity, the portion formed by the parietal and frontal bones is exposed; the parietal is traversed longitudinally by a thin, but high, median crest; the part of the bone forming the sides of the small cerebral cavity are convex, and the breadth of the bone diminishes towards the occiput; here it divides into two branches, which pass outwards more transversely than in existing lizards. There is no perforation either in the parietal bone or in the coronal suture. At the anterior part of the parietal crest two lines diverge from each other at a right angle to the upper part of the orbit, and separate the post-frontals. A nearly transverse suture divides the fore-part of the parietal from the post-frontals. The median frontal bone is single, like that of the New World Monitors (*Thorictes*, *Tejus*, &c.) and the Iguanæ, and not divided, as in the Varanians. It expands slightly as it advances towards the fore-part of the orbits: the oblique lines dividing the median frontals from the post-frontals, and the supraorbital ridges are raised, so that the interspace is slightly concave, and the surface is also broken by irregular elevations and depressions. Each post-frontal is divided by a nearly transverse suture. The posterior frontal completes the upper and outer part of the orbit by a thin, well-defined, curved plate; an irregular obtuse ridge descends in a nearly vertical direction behind this plate, and then the posterior frontal contracts and is extended backwards in the form of a long compressed process, gradually terminating in a point, which overlaps the zygomatic bone. This bone forms the medium of union between the long posterior frontal and the mastoid.

The tympanic bone presents a slight sigmoid flexure, and is expanded transversely at its distal extremity; its posterior surface is exposed, which is convex and rounded, and continued externally in the form of a thin plate, which is concave behind. The thick convex stem divides near the lower end into two ridges, which diverge, like the condyles of a humerus, and intercept the trochlea, on which the concave articulation of the lower jaw plays. The tympanic trochlea is convex from behind forwards, concave from side to side. The orbit is large, nearly circular in form, and its bony frame is complete; this is formed above by the median, anterior, and posterior frontals; before by the anterior frontal and lachrymal; below by the malar; and behind by the malar and posterior frontal.

The malar bone, as in most lizards, is long, slender, and bent upon itself, but its external surface is unusually concave, the orbital plate bending outwards like the corresponding rim formed by the frontal bone. The anterior or horizontal branch of the malar gradually tapers to a point which is wedged in between the lachrymal and maxillary bones. The posterior branch ascends at nearly a right angle, and is applied obliquely to the posterior part of the descending process of the posterior frontal. At the angle between the two portions of the malar a process is continued backwards for about half an inch, but its extremity is broken off. The lachrymal bone presents the same relative position and size as in the *Thorictes*, *Lacerta*, and most lizards; a tubercle rises from about the middle of its external surface. The superior maxillary is a broad vertical triangular plate of bone, with a smooth external surface;

the alveolar border projects externally like a ridge, above which the bone is slightly concave. This ridge appears to be slightly dentated; it overlaps the corresponding alveolar border of the lower jaw. The posterior and superior margin of the maxillary is slightly concave, and joins the malar and lachrymal bones and a small part of the prefrontal: the anterior superior margin joins the upper half of the elongated intermaxillary, which divides it from the nasal bones and the external nostril; the lower side or base of the triangle, which forms the alveolar border, is convex.

The most singular character of the cranium of the present fossil genus is afforded by the intermaxillary bones. These, in their length and regular downward curvature, give to the fore-part of the skull the physiognomy of that of a parrot or accipitrine bird, but they differ essentially from both those of the bird and lizard in being distinct from each other throughout their whole length, and in gradually diminishing to their inferior extremity, which is not expanded and continued laterally to form any part of the alveolar border of the upper jaw. Each intermaxillary bone is a slender, subcompressed, elongated bone, bent so as to describe a quarter of a circle; the upper half is thinner, but rather broader than the lower half, and is wedged in between the superior maxillary, frontal and nasal bones; the lower half, which is somewhat narrower but thicker, and is subcylindrical, *projects freely downwards beyond the superior maxillary bone*; the deep anterior extremity or compressed symphysis of the lower jaw is applied to the posterior surface of these produced extremities of the two intermaxillaries, when the mouth is closed. The two intermaxillaries converge towards each other from their posterior origins, and are in close contact with each other, where they form the singular curved projecting beak.

The external nostril is single and situated between the upper diverging ends of the intermaxillaries, but a fracture of the fossil at this part prevents the precise form of this aperture, or the mode of termination of the nasal bones, from being determined. The nasal bones, if not actually absent in the present fossil, as in most Chelonians, must have been extremely small, as in the Chameleons.

The lower jaw is of considerable depth, and exceeds, as in most Saurians, the length of the cranium. The articular cavity is deep and wide; the angle of the jaw is broken off directly behind this cavity on the left side, but is continued backwards beyond it for more than half an inch on the right side. The ramus gradually expands in the vertical direction, and becomes thinner from side to side, as it advances forwards to about its middle part, which is just behind the orbit, where it measures 11 lines in depth; it then begins gradually to diminish vertically to the symphysis, which again slightly increases vertically to its termination, which is obliquely truncated, much compressed laterally, and applied against the deflected extremities of the produced intermaxillaries. The posterior half of the maxillary ramus is slightly convex externally, the anterior narrower part is slightly concave; the superior margin describes a slight but graceful sigmoid curve, convex posteriorly, and concave anteriorly, where it is applied to the convex alveolar border of the upper maxillary bone, to the inner side of which it is closely adapted. The alveolar border forms an external, convex, projecting ridge, analogous to that of the upper jaw. The composite structure of the lower jaw is very clearly displayed in the fossil. The articular piece is short, but is continued forward as a slender process below the angular piece, as in the *Varanus*; the angular piece is relatively larger than in the *Varanus*, and presents nearly the same proportions as in the *Thorictes*. The supra-angular is larger, and occupies the proportion of the jaw formed by the supra-angular and coronoid elements in *Thoriotes* and other lizards: the opercular element extends further upon the outside of the jaw from its lower margin than in the existing lizards; the *Thoriotes* again, in this respect, coming nearest to the *Rhynchosaurus*: the dentary element constitutes the rest of the outer part of the ramus, but not the slightest trace of teeth is discernible.

The present singular and highly interesting cranium seems to have been preserved with the mouth in the naturally closed state, and the upper and lower jaws are in close contact. In this state we must suppose that they were originally buried in the sandy matrix which afterwards hardened around them; and since lizards, owing to the unlimited reproduction of their teeth, do not become edentulous by age, we must conclude that the state in which the *Rhynchosaurus* was buried, with its lower jaw in undisturbed articulation with the head, accorded with its natural condition, while living, so far as the less perishable hard parts of its masticatory organs were concerned. Nevertheless, since a view of the inner side of the alveolar border of the jaws has not been obtained, we cannot be assured of the actual edentulous character of this very singular Saurian; for in the genera *Agama* and *Chameleo* the dental system, seen only from the outside of the jaws, is represented by mere dentations of the alveolar border, and the anchylosed bases of the teeth, the crowns of which really form the dentations, are recognizable only by an inside view. The indications of the dental system are at any rate more obscure in the *Rhynchosaurus* than in any existing Lacertian; the dentations of the upper jaw are absolutely feebler than in the Chameleon, and no trace of them can be detected in the lower jaw, where they are strongest in the Chameleon. The absence of the coronoid process in the *Rhynchosaurus*, which is conspicuously developed in all existing lizards, corresponds with the unarmed condition of the jaw, and the resemblance of the *Rhynchosaurus* in this respect to the *Testudo* (*Chelys*) *ferox*, would seem to indicate that the correspondence extended to the toothless condition of the jaws. The resemblance of the mouth to the compressed beak of certain sea-birds, the bending down of the curved and elongated intermaxillaries, so as to be opposed to the deep symphysial extremity of the lower jaw, are further indications that the ancient Rhynchosaur may have had its jaws encased by a bony sheath, as in birds and turtles.

A small flattened triangular plate, which adhered to the posterior part of the skull, was suspected by Dr. Ward to be a tooth; it appeared to me, from the character of the exposed surface, to have at least equal claims to be regarded as a dermal scute. In preparing the mould of the cranium this part was detached and lost, a circumstance which I have much regretted, since it prevented my applying to it the test of a microscopical examination.

I proceed now briefly to notice the other portions of the skeleton, which, from their size, texture, and community of stratum and locality, are with much probability referable to the *Rhynchosaurus*.

Considerable portions of two rami of two distinct lower jaws, in portions of sandstone from the Grinsill quarries, show the same structure as that of the jaw in the cranium above described; the thick edentulous alveolar border is bounded below on the outside by the longitudinal channel; the lower border of the ramus is thick and smoothly rounded, it is somewhat abruptly constricted immediately behind the deflected extremity or symphysis. The structure of the bone is very compact; the fractured end demonstrates the large cavity, common in reptiles, which is included between the opercular and dentary pieces.

One piece of fine-grained sandstone contains a considerable proportion of four of the dorsal vertebræ in a connected chain, which measures 1 inch 10 lines. Near this chain of four and a smaller part of a fifth vertebra, there are portions of four ribs. These have a single, not a bifurcated head; they are subcompressed, slightly and pretty uniformly curved, and grooved longitudinally on both sides; the longest portion of rib measures 2 inches, following the curvature. The same fragment of sandstone contains three flat bones, which offer several striking modifications, whether they be compared with the constituents of an os innominatum or of the scapular arch.

The most entire of the three bones consists of a thicker articular end; a long, broad and thin plate, forming the body of the bone; and a moderately long trihedral process, given off from the convex margin near the articular end. In these characters the comparative anatomist conversant with the modifications of the skeleton in recent and extinct Saurians will recognize a resemblance to the scapula of the Iguanodon and Hylæosaur, in a minor degree to the ischium of the Crocodile, and somewhat more remotely, to the pubis of the Tortoise. The trihedral process, in the second comparison, would match the anterior pubic process of the Crocodile's ischium, but the entire bone would differ from that of the Crocodile in the slenderness of the pubic process, in the greater breadth and less length of the body of the bone, and in its extreme thinness; it increases in thickness, however, as in the Crocodile's ischium, towards the articular end. The correspondence of the trihedral process of the bone in question with the long spinous process of the Chelonian pubis, is less close than the one just discussed. If the present well-marked bone of the Rhynchosaur be regarded as a scapula, it is to that bone in the *Dinosauria* that it offers most resemblance; and the prismatic process would then correspond with the one sent off from the anterior part of the coracoid articular surface in the scapula of the Hylæosaur and Iguanodon. It is the concavity at the neck of the bone, at the side opposite that from which the process is sent, which gives it a nearer resemblance to the Dinosaurian scapula than to the Crocodilian ischium; it differs from the scapula of the Crocodile in having the posterior margin, beyond the neck, straight instead of convex; the corresponding margin in the ischium being concave. The blade of the bone, considered as scapula, is broader and shorter than in either the Dinosaurs or Crocodiles. Its outer surface is slightly convex: supposing it to be placed vertically upon the thicker articular end, the prismatic process is directed forwards and downwards. There are a few small pits or inequalities near the neck or thick articular margin in the present fossil. The outer surface of the plate is marked with extremely fine striæ, radiating from the neck.

	In.	Lin.
Length of the bone	1	8
Breadth of neck	0	5½
Breadth of base	1	0
Length of trihedral process	0	8

Coracoid.—The remains of a thin and broad plate of bone, attached by a short neck to an apparently articular thickened head or process, might be compared with a coracoid, as it resembles, so far as it is preserved, the coracoid of lizards, more than it does any other known bone; there is not, however, the perforation near the articular surface. The breadth of the neck is 6 lines, that of the body of the bone which remains 13 lines; the length, or diameter at right angles to the above, is 10 lines; the bone is thinned off to an edge, which is gently convex.

Humerus.—A third bone, imbedded in the same piece of sandstone at a little distance from the preceding, is expanded at both extremities, contracted and twisted in the middle; one of the expanded extremities, apparently the proximal end, is nearly entire; it terminates by an irregular convex border, not thinned off to an edge, but adapted to the formation of a joint, and to the attachment of cartilage. The exposed surface of the expanded head is concave from side to side., somewhat resembling the expanded and bent pubic plate in lizards. The opposite extremity is broken across; it shows the commencement of a slight longitudinal ridge near its middle part. This bone bears most resemblance to a humerus, but I am at present unable to determine it unequivocally. If compared with the left pubis of Lacertians, the entire and bent extremity corresponds with the median portion of that bone; but the middle part or stem is much longer in the fossil, and the broken end, which would agree with the acetabular end of the pubis, is too thin to have entered into the formation of such a cavity in the fossil; it likewise wants the perforation which characterizes the pubis in lizards. The same thinness and imperforate condition of the fractured end oppose the comparison of the present bone with the coracoid of the Crocodile.

	In.	Lin.
Length of this bone as far as complete	1	9
Breadth of middle	0	3
Breadth of entire expanded extremity	0	10

In the slab containing the above-described bones, there are other fragments of bone, but too small and imperfect for profitable description. Those of which I have endeavoured to make the form and analogies intelligible, though evidently peculiar, as might be expected in a Saurian with so strange a head, and perhaps with a hind-toe directed backwards as in birds, may be regarded as, most probably, constituents of a strong and well-developed pectoral arch, and a humerus; and they indubitably indicate a mechanism for locomotion on land, which would well agree with that of the animal that has left the impressions of its footsteps upon the same sandstone.

Radius and Ulna.—Another piece of coarse-grained sandstone from the same quarry contains a series of seven or eight vertebræ in a very fragmentary state, also two or three ribs, rather more slender and not so distinctly grooved as in the fine-grained slab, and the proximal extremities of two long bones, which may be best compared with the radius and ulna. The shaft of the radius is more slender than that of the ulna; one side is flat, the other convex; it expands and assumes a subtrihedral figure, by the development of a slight longitudinal ridge; its proximal end is compressed and more suddenly expanded; its breadth is 2¼ lines, that of the shaft of the bone is 1 line. The impression, partly broken away in the stone, indicates the greater expansion of the distal end of this bone, with a length of 1 inch 3 lines. The proximal end of the ulna has a distinct trihedral figure, and the expanded extremity is produced backwards, so as to indicate the olecranon; the breadth of the head is 4 lines, that of the middle of the shaft is 2½ lines. There is a portion of a broad and flat bone in this piece which may have belonged to the scapular arch.

Ilium.—In another piece of stone, with the other portion of the same chain of five vertebræ, there is a broad and flat bone, apparently terminating in a long narrow process at one end, which may be an ilium; its length is indicated to be at least 1 inch 7 lines.

Femora.—A thin piece of burr or coarse-grained sandstone contains the articular end of a broad and flat bone, in which the raised oblong surface of the joint is divided by a smooth channel, and may be compared with the cotyloid portion of the ilium; the same piece of stone contains the shafts of two long bones, most probably femora. The length of the most perfect of these is 2 inches, and this does not include the distal end; the diameter of the middle of the shaft is 2½ lines; the surface of the preserved middle part shows the shaft to have been somewhat angular; the compact outer wall of the bone is about a quarter of a line thick; a large medullary cavity extends the whole length of the shaft, agreeing with the indications of terrestrial habits yielded by the bones before described; the extremities of the femora are spongy, but much decomposed and stained with iron-mould.

There are few genera of extinct reptiles of which it is more desirable to obtain the means of determining the precise modifications of the locomotive extremities than the *Rhynchosaurus*. The fortunate preservation of the skull has brought to light modifications of the Lacertine structure leading towards Chelonia and Birds, which before were unknown; the vertebræ likewise exhibit very interesting deviations from the Lacertian type. The entire reconstruction of the skeleton of the *Rhynchosaurus* may be ultimately accomplished, if the same interest in the collection and preservation of the fossils of the Grinsill quarries be continued, as has already produced so important an accession to Palæontology through the well-directed zeal of Dr. Ogier Ward and other members of the Literary and Scientific Association at Shrewsbury.

THECODONTS.

Among the inferior or squamate Saurians there are two leading modifications in the mode of attachment of the teeth, the base of which may be either anchylosed to the summit of an alveolar ridge, or to the bottom of an alveolar groove, and supported by its lateral wall. These modifications are indicated respectively by the terms "acrodont" and "pleurodont." A third mode of fixation is presented by some extinct Saurians, which, in other parts of their organization, adhere to the squamate or Lacertine division of the order, the teeth being implanted in sockets, either loosely or confluent with the bony walls of the cavity; these I have termed the "thecodont"* Lacertians: the most ancient of all Saurians belong to this group.

Thecodontosaurus, Riley and Stutchbury.—In the dolomitic conglomerate at Redland near Bristol, a formation considered to belong to the oldest or lowest division of the new red sandstone series, remains of reptiles have been discovered by Dr. Riley and Mr. Stutchbury†, which are allied in the form of their teeth to the typical Varanian Monitors, but differ in having the teeth imbedded in distinct sockets; to this condition, however, the *Varani*, among the squamate Saurians, make an approach in the shallow cavities containing the base of the teeth along the bottom of the alveolar groove.

In the ancient extinct genus in question the sockets are deeper, and the inner alveolar wall is nearly as high as the outer one; the teeth are arranged in a close-set series, slightly decreasing in size towards the posterior part of the jaw; each ramus of the lower jaw is supposed to have contained twenty-one teeth. These are conical, rather slender, compressed and acutely pointed, with an anterior and posterior finely-serrated edge, the serratures being directed towards the apex of the tooth, as in the genus *Rhopalodon* of G. Fischer; the outer surface is more convex than the inner one; the apex is slightly recurved; the base of the crown contracts a little to form the fang, which is subcylindrical. The pulp-cavity remains open in the base of the crown. In their microscopic structure, the teeth of the *Thecodontosaurus* closely correspond with that of the teeth of the *Varanus*, *Monitor*, and *Megalosaurus*. The body of the tooth consists of compact dentine, in which the calcigerous tubes diverge from an open pulp-cavity at nearly right angles to the surface of the tooth; they form a slight curve at their origin, with the concavity directed towards the base of the tooth; then proceed straight, and at the periphery bend upwards in the contrary direction. The diameter of the calcigerous tube is $\frac{1}{30,000}$th of an inch; the breadth of the interspace of the tubes is $\frac{1}{8000}$th of an inch. The crown of the tooth is invested with a simple coat of enamel.

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* Odontography, part ii. p. 266.

† Geological Transactions, 1836, p. 349.

This microscopic examination of the structure of the teeth, which I have been enabled to make by the kindness of Mr. Stutchbury, satisfactorily establishes the distinction between the Saurian of the Bristol conglomerate and the reptiles of the later member of the new red sandstone system in Warwickshire, which I have described under the name of *Labyrinthodon*.

Palæosaurus, Riley and Stutchbury.—In the formation which contained the jaw and teeth of the *Thecodontosaurus*, two other teeth were separately discovered, differing from the preceding and from each other; the crown of one of these teeth measuring 9 lines in length and 5 lines in breadth. It is compressed, pointed, with opposite trenchant and serrated margins; but its breadth as compared with its length is so much greater than in the *Thecodontosaurus*, that Dr. Riley and Mr. Stutchbury have founded upon it the genus *Palæosaurus*, and distinguish it by the specific name of *platyodon*, from the second tooth, which they refer to the same genus under the name of *Palæosaurus cylindrodon*. The portion of the tooth of the *Palæosaurus cylindrodon* which has been preserved, shows that the crown is sub-compressed and traversed by two opposite finely-serrated ridges, as in the *Thecodontosaurus* and *Rhopalodon*; its length is 5 lines, its breadth at the base 2 lines.

The vertebræ associated with these teeth are biconcave, with the middle of the body more constricted, and terminal articular cavities rather deeper than in *Teleosaurus*; but they are chiefly remarkable for the depth of the spinal canal at the middle of each vertebra, where it sinks into the substance of the centrum; thus the canal is wider, vertically, at the middle than at the two ends of the vertebra: an analogous structure, but less marked, obtains in the dorsal vertebræ of the *Rhynchosaurus* from the new red sandstone of Shropshire.

Besides deviating from existing lizards in the thecodont dentition and biconcave vertebræ, the ancient Saurians of the Magnesian conglomerate also differed in having some of their ribs articulated by a head and tubercle to two surfaces of the vertebra, as at the anterior part of the chest in Crocodiles and Dinosaurs. The shaft of the rib was traversed, as in the Ichthyosaur and Rhynchosaur, by a deep longitudinal groove. Some fragmentary bones indicate obscurely that the pectoral arch deviated from the Crocodilian and approached the Lacertian or Enaliosaurian type in the presence of a clavicle and in the breadth and complicated form of the coracoid. The humerus appears to have been little more than half the length of the femur, and to have been, like that of the *Rhynchosaurus*, unusually expanded at the two extremities. The femur is thus described by the discoverers of the present thecodont reptiles:—

"Two femurs, in a tolerable state of perfection, have fortunately been found; one, of the right side, exhibiting nearly the whole of the bone, the inferior condyles only wanting; the other is the left, and exhibits the condyles, but is very imperfect at the superior extremity. The first mentioned measures 10 inches in length; from the head to the middle of the trochanter 3 inches $\frac{6}{10}$ths; from the trochanter to the inferior condyle 5 inches $\frac{7}{10}$ths. In the left femur the transverse diameter of the condyles is 2 inches $\frac{3}{10}$ths; the centre of the cylinder 1 inch. They are curved in two directions upon the axis, giving them somewhat a twisted form, or the shape of a long *ſ* antero-posteriorly. The trochanter is well preserved, wedge-shaped, and of considerable size, as may be seen by reference to the figures. The articular head is flattened at the space between the trochanter, and the articular extremity is more curved than any other part of the bone: the centre is nearly round, but a slight elevation or ridge exists on its posterior surface, in the situation of the linea aspera of the human femur. The condyles are flattened, the outer one being the larger; there is a deep depression between them posteriorly, and a very slight one anteriorly.

"On an attentive comparison of these femurs with those of the Crocodile and Megalosaurus, we again recognise a resemblance. A comparison with the femurs of the Monitors evidently shows that our animal cannot have belonged to that family. The femurs of the Monitor are much less curved, being nearly straight, and the trochanter is much nearer the articular extremity; characters sufficiently showing a wide difference between them."

The tibia, fibula, and metatarsal bones manifest, like the femur, the fitness of the thecodont Saurians for progression on land. The ungual phalanges are sub-compressed; curved downwards, pointed, and impressed on each side with the usual curved canal.

The general conclusions which may be drawn from the knowledge at present possessed of the osteology of the *Thecodontosaurus* and *Palæosaurus*, the antiquity of which the discoverers of these genera regard as being greater than that of any other vertebrated animals, excepting fishes, are, that in their thecodont type of dentition, biconcave vertebræ, double-jointed ribs, and proportionate size of the bones of the extremities, they are nearly allied to the *Teleosaurus*; but that they combine a Lacertian form of tooth, and structure of the pectoral and probably pelvic arch with these Crocodilian characters, having distinctive modifications, as the moniliform spinal canal, in which, however, the almost contemporary Rhynchosaur participates. It would be interesting to ascertain whether the caudal vertebræ are characterized, as in the Thuringian Protorosaur, by double diverging spinous processes*.

Cladyodon, nob.—In the new red sandstone (Keuper?) of Warwick and Leamington, there occur detached, pointed, trenchant, recurved teeth, the crowns of which are sometimes 1 inch 4 lines in length, and 5 lines across the base: they have been found in the same quarries as those containing the remains of the *Labyrinthodon*. In their compressed form, anterior and posterior serrated edges, sharp points, and microscopic structure, these teeth agree with those of the Saurian reptiles of the Bristol conglomerate. In their breadth, as compared with their length and thickness, they are intermediate between the *Thecodontosaurus* and the *Palæosaurus platyodon*; but they are larger, with longer and more recurved crowns, and thus more nearly approach the form characteristic of the teeth of the *Megalosaurus*†. From these teeth, however, they differ in their greater degree of compression, and in a slight contraction at the base of the crown; I therefore indicate the genus, of which, as yet, only the teeth are known, by the name of *Cladyodon*, and the species from the Warwickshire sandstones by the name of *Cladyodon Lloydii*, in testimony of the friendly aid of Dr. Lloyd of Leamington, to whose zealous co-operation I owe the materials for the description of the teeth of the present genus, and the still more remarkable ones of the British species of *Labyrinthodon*, with which the teeth of the *Cladyodon* are associated.

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* This structure I have ascertained in the original specimen described by Spener, now preserved in the Hunterian Museum.

† One of the teeth of the *Cladyodon* is figured in the Memoir of Messrs. Murchison and Strickland on the Warwick Sandstones, Geol. Trans., second series, vol. v. pl. xxviii. fig. 6.

Order PTEROSAURIA.

The term *Ornithocephalus*, originally imposed by Soemmering on the genus *Pterodactylus*, Cuv., which is the type of the present extinct order of reptiles, would be much more applicable to the *Rhynchosaurus*; for although a more striking approach to the class of birds is made by the modification of the pectoral extremity which endowed the Pterodactyle with the power of flight, it is precisely in the structure of the cranium that it adheres most closely to the ordinary Saurian type of structure.

The genus *Pterodactylus* was ranked among the swimming-birds by Blumenbach, with the cheiropterous Mammalia (Bats) by Hermann and Soemmering, and has been proved to belong to the order of Reptiles by Cuvier. The *Pterodactylus longirostris*, from the lithographic slate of Pappenheim, was the earliest known species; the *Pter. brevirostris*, *Pter. medius*, and *Pter. grandis*, were next established, and subsequently the British species *Pter. macronyx* was determined by Dr. Buckland, from remains discovered in the lias of Lyme Regis, and which, before they came under the discriminative glance of the Oxford Professor, had passed as the bones of birds.

Of this species Dr. Buckland describes the principal bones of the extremities, and several vertebræ; the cranium has not yet been discovered. The valuable subject of the Professor's memoir is deposited in the British Museum; the Memoir is contained in the third volume of the second series of the Transactions of the Geological Society, and an accurate figure of the specimen is given, of the size of nature, at plate xxvii.*

A second stratum, in which the remains of Pterodactyles have been detected by Dr. Buckland, is the oolite slate of Stonesfield. Some fine specimens of the long bones of the extremities of Pterodactyles from that locality, in the collection of John Hunter, were referred by that celebrated anatomist to the class of birds.

SAURIA INCERTÆ SEDIS.

Polyptychodon.—A large species of Saurian is indicated by thick conical teeth, having the general character of those of the Crocodile, but distinguished by numerous, closely-set, longitudinal ridges, which are continued, of nearly equal length, to within 2 lines of the apex of the crown. These teeth have been described and figured in my 'Odontography' under the name of *Polyptychodon*. In their size and general form these Saurian teeth resemble those of the great sauroid fish, *Hypsodon*, Ag., but may be distinguished by the solidity of the crown, and the conformity of the structure of the dentine with that of the Crocodiles; also by the ridges on the exterior of the crown of the Hypsodon's teeth being alternately long and short, and terminating abruptly at different but commonly greater distances from the apex than in *Polyptychodon*, the interspaces between the longer ridges widening as they approach the apex. The tooth of the *Polyptychodon* is slightly and regularly curved, and invested with a moderately thick layer of enamel, of which substance the ridges are composed, the surface of the outermost layer of dentine being smooth. A tooth of this reptile from the lower greensand (Kentish-rag quarries) near Maidstone, in the collection of Mr. Benstead of that town†, has a crown 3 inches long, and 1 inch 4 lines across the base. The compact dentine is resolved by decomposition into a series of superimposed thin hollow cones, and the short and wide conical pulp-cavity is confined to the base or fang. The cavity of the tooth in *Hypsodon* would appear to have been much larger, as it is in many predatory fishes, in which the teeth are more rapidly shed and renewed than in Crocodilian reptiles.

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* See also the interesting chapter on "Flying Saurians" in the 'Bridgewater Treatise,' vol. i. p. 221.

† Presented by that gentleman, since the reading of this Report, to the Museum of the Royal College of Surgeons.

The teeth of *Polyptychodon* differ from those supposed to have belonged to *Poikilopleuron*, in the ridges of the crown being more numerous and close set, and in the transverse section being nearly circular instead of being elliptical: from the teeth of *Pliosaurus* those of *Polyptychodon* differ in being round and not three-sided, and in having longitudinal ridges over the whole surface of the crown; and from the teeth of *Mosasaurus* they differ in being ridged and not smooth.

Gigantic Fossil Saurian from the Lower Greensand at Hythe.

Under this head I have to notice some remains of a Saurian of marine habits, but most probably of the Crocodilian order, as gigantic as the *Cetiosaurus* or *Polyptychodon*, but, in the absence of dental and vertebral characters, not referable to any known genus. These remains were discovered by H. B. Mackeson, Esq. of Hythe, in the greensand quarries near that town, and include portions of the iliac, ischial and pubic bones, a large proportion of the shaft of a femur, parts of a tibia and fibula, and several metatarsal bones. In consequence of the absence of vertebræ and teeth, the present observations will be limited to indicating the characters by which these remains differ from previously known extinct genera of Saurians. In the first place, as the femur and other long bones have no medullary cavities, but a central structure composed of coarse cancelli, it is evident that the animal of which they formed part was of marine habits; but the best-preserved bone being a femur, this circumstance, independently of the size and shape of the metatarsals, at once negatives the idea that these remains belonged to the Cetacean order, whilst the form and proportions of the metatarsals equally forbid their reference to any other Mammalian genus.

Femur.—The portions of this bone secured by Mr. Mackeson include about the two distal thirds, excepting the articular extremity; its length is 2 feet 4 inches; its circumference in the middle, or smallest part of the shaft, is 15 inches 6 lines, and at the broken distal end, 2 feet 5 inches. These dimensions prove that the animal was equal to the most gigantic described *Iguanodon**. If the supposition of the proportion of the femur which has been preserved be right, this bone differs from that of the *Iguanodon*, not only in the want of a medullary cavity, but also in the absence of the compressed process which projects from the inner side of the middle of the shaft. The bone also expands more gradually than in the femur of the *Iguanodon*, and the posterior part of the condyles must have been wider apart in consequence of the posterior inter-condyloid longitudinal excavation being longer and wider.

Tibia and Fibula.—The portion of a tibia which has been preserved is compressed near its head, and the side next to the fibula is slightly concave. The longest transverse diameter is 8 inches 9 lines, and the two other transverse diameters at right angles to the preceding, give respectively 3 inches 3 lines, and 2 inches 6 lines. The bone soon assumes a thicker form, its circumference at about one-third from its proximal end being 16 inches 6 lines. The cancelli occupying the central portion of the bone are arranged in a succession of layers around a point nearest the narrower end of the transverse section. Lower down the tibia again becomes compressed, and towards the distal end the transverse section exhibits the form of a plate bent towards the fibula, and its narrowest transverse diameter is $2\frac{1}{2}$ inches.

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* The length of the largest femur yet obtained of this Saurian is 4 feet 6 inches, its smallest circumference 1 foot 10 inches.

The portion of the fibula is $11\frac{1}{2}$ inches long. In the middle it is flat on one side, slightly concave on another, and convex on the two remaining sides. It presents the same cancellous structure as the tibia, but the concentric arrangement of the layers of cells is more exact. Towards the opposite end of the bone the concave side becomes first flat, and is then produced into a convex wall, terminating one end of a transverse section of a compressed and bent thick plate of bone.

Metatarsals.—These bones exhibit the characteristic irregularity of length of the Crocodilian metatarsals. Of two imbedded in the rock, and apparently the innermost and second, of the left hind-foot, the former or smaller measured 1 foot in length and the latter 2 feet, having a diameter of 8 inches at its greater end, and of 4 inches 5 lines at its narrowest or middle part, and of 6 inches at its other extremity, which was imperfect. The whole of the bone within the compact outer crust consisted of cells varying from a half to two-thirds of a line in diameter. Portions of four other detached metatarsals are described.

Ilia, Ischia, Pubis, and Coracoid Bone.—These bones conform in the main to the Enaliosaurian type. The remains of the ilia are flat and nearly straight, and they gradually but slightly widen towards one end. Of one ilium a portion, 25 inches long and 10 inches across at the broadest end, is preserved, and of the other a fragment 20 inches in length.

The mesial extremities of the pubis and ischium are preserved in the same block of stone. The pubis differs from the Crocodilian type in its greater breadth. The portion exposed in this block is principally convex, but it becomes concave towards the opposite or median margin. At its broadest part it is 13 inches across, and its length is 17 inches. This expanded extremity is rounded, and the diameter of the corresponding expanded extremity of the ischium, which is obliquely truncated, is 9 inches. In another block of stone the expanded extremity of the opposite pubis is preserved, and measures 14 inches across and 22 inches in length.

The bone which bears most resemblance to a coracoid is 2 feet in length and 17 inches in its greatest breadth, and it varies in thickness from 3 to 5 inches. The breadth of this bone indicates the great development of the muscles destined for the movement of the fore-leg, whence it may be inferred that the anterior extremities were more powerfully and habitually used in progressive motion than in the Teleosaurian Crocodiles.

It will be sufficiently apparent, from the brief notice of the principal characters of these interesting remains here given, that they cannot have belonged to any of the genera of the great ambulatory terrestrial Dinosaurs; and, on the other hand, the length, thickness, and form of the condyles of the femur, and the size and shape of the metatarsal bones equally remove the Enaliosaurs from the pale of comparison.

There then remain, as claimants of the fossils in question, first, the great *Mosasaurus* of the Cretaceous formations, the locomotive extremities of which have not been yet discovered; secondly, the equally gigantic *Cetiosaurus brevis*, associated with the *Iguanodon* in the Wealden, and, from its organization, more likely than the *Iguanodon* to be found in later marine deposits; finally, the Reptile of the Maidstone greensand, to which the name of *Polyptychodon* has been provisionally assigned from the configuration of its teeth. But, since the teeth of the genus *Cetiosaurus* are not yet determined, the identity of this genus with *Polyptychodon* is open to suspicion; and subsequent discoveries may demonstrate that the great Saurian of the Hythe greensand indicated by bones of the extremities, that of the Maidstone greensand by its teeth, and that of the Wealden formation recognized by its vertebræ, are all parts of the same extinct reptile.

Genus *Rysosteus*, nob.

I have been favoured by Mr. Johnson of Bristol, with the opportunity of examining a small anterior dorsal vertebra, (No. 177, of his interesting Collection,) half imbedded in its pyritic matrix, from the Bone-bed of Aust Passage, near Bristol.

Both articular ends of the body of this vertebra are concave, but deeper than in *Teleosaurus*, with a central short transverse linear impression. The lower part of the side of the body is raised into an obtuse longitudinal ridge, above which, between it and the transverse process, is a wide but not deep depression. The centrum slightly expands to the two extremities, which have a circular contour. The transverse process is broken off: its base, which is as deep as long, rests in a small proportion upon the centrum, but chiefly upon the side of the neurapophysis, the limits of which are not defined by a persistent suture. The neural arch rests upon the whole antero-posterior extent of the upper part of the centrum, rises nearly vertically to a height not quite equal to that of the centrum, then slopes abruptly inwards to support the base of the spine. This is nearly equal in antero-posterior extent to the centrum, and slightly increases in that direction by inclining over the interspace of the posterior oblique processes: it also slightly gains in thickness, and is terminated by a flat and rough surface, the contour of which is nearly parallel with that of the under surface of the centrum. The sides of the spine for two lines below the summit are wrinkled* or impressed by vertical or slightly oblique coarse grooves. The posterior oblique process is moderately long and slender; its flat elliptical articular surface looks downwards and slightly outwards. The non-articular surfaces of the vertebra are smooth, except near the summit of the spine, the lateral ridges and grooves of which form the chief characteristic of the present vertebra.

This vertebra, though it resembles those of a few species of Plesiosaur in the depth of its terminal articular surfaces, differs too much in its length and lateral compression to be referable to that genus; the rough and thick truncated summit of the spinous process rather indicates the species to have belonged to the loricate family of Saurians. It differs from the vertebræ of the Teleosaur and other known Amphicœlian Crocodiles in the form and vertical thickness of the transverse processes, in the lateral longitudinal ridge of the centrum, and in the antero-posterior extent and form of the spinous process. It differs from the vertebræ of the Labyrinthodon in the articular ends being at right angles to the axis of the centrum and not oblique; in the greater vertical thickness of the transverse process; and in the spine not being suddenly expanded and flattened at the summit, as in the dorsal vertebræ of the *Labyrinthodon*.

The following are dimensions of the vertebra of *Rysosteus*:—

	Lines.
Antero-posterior extent of centrum	11
Transverse diameter of articular end	5
Vertical diameter of articular end	6
Vertical diameter of entire vertebra	16
Antero-posterior extent of spinous process	10

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* The name here proposed for the Saurian of the Bone-bed, from ῥυσὸς wrinkled, ὀστέον a bone, relates to this structure.

I have received other portions of *Rysosteus* from the Bone-bed at Westbury Cliff, on the Severn, eight miles from Gloucester.

Two spinous processes of fractured vertebræ are conspicuous and readily recognizable by their wrinkled surface and great antero-posterior extent; they agree also in size with the vertebra from Aust Passage, and seem to be evidently of the same species.

The distal end of a Saurian humerus and a nearly entire femur are associated with these vertebral fragments. The humerus has an angular and twisted shaft, and greatly expanded articular extremities, the surface of which is ridged like the spinous processes, but with somewhat wider intervals.

The femur equals the length of three vertebræ and a half; resembles that of the *Teleosaurus* in shape, but has the outer surface of the expanded extremities wrinkled, though in a minor degree than in the humerus. The correspondence of the long bones in size, and in the wrinkled character of part of their surface with the vertebræ, almost demonstrates that they belong to the same species of Saurian.

Order CHELONIA.

Family TESTUDINIDÆ, Tortoises, or Land-Tortoises.

New Red Sandstone Tortoises.—The most ancient of the evidences of Reptiles of the Chelonian order, in British formations, appear to be referable to Land-tortoises. The foot-prints upon the thin superimposed strata of the new red sandstone quarries at Corn-Cockle Muir, of which an account is given by Dr. Duncan in the Transactions of the Royal Society of Edinburgh for the year 1828, and those subsequently discovered in the same ancient formation at the quarries of Craigs, two miles east of the town of Dumfries, are regarded by Dr. Buckland as bearing most resemblance to the foot-prints of a small species of tortoise*.

Oolite Tortoises.—The impressions of horny scutes, about the size of those covering the carapace of a tortoise ten inches in length, occur not unfrequently in the oolitic slate of Stonesfield, and leave a light brown stain upon the matrix. These correspond so closely in form and in the arrangement and distinctness of the concentric lines with those of existing tortoises†, that the position which they originally held on the carapace may often be determined.

Family EMYDIDÆ, Fresh-water Tortoises.

Emys, sp. indet.—In the museum of Prof. Bell there is a specimen of an *Emydian* Chelonite from the Eocene clay near Harwich, which differs from the *Emys testudiniformis* of Sheppey in its flatter figure.

The carapace is elliptical, gently convex at the middle and concave at the sides, the margins being slightly raised. The external surface of the osseous buckler is slightly rugous; the length of the carapace is 11 inches; its breadth at the suture between the fifth and sixth rib is 10 inches.

The first vertebral plate is nearly flat; the middle part of its posterior margin extends backwards about one line and a half. The second vertebral plate is of an oblong quadrangular figure, 6 lines in breadth: the third vertebral plate is six-sided and 8 lines in breadth, the two anterior sides being the shortest: the tenth and eleventh vertebral plates are broad.

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* "On comparing some of these impressions with the tracks which I caused to be made on soft sand, clay, and upon unbaked pie-crust, by a living Emys and *Testudo Græca*, I found the correspondence with the latter sufficiently close, allowing for difference of species, to render it highly probable that the fossil footsteps were also impressed by the feet of land-tortoises."—*Bridgewater Treatise*, vol. i. p. 261.

† The *Emys centrata* is, however, so denominated on account of the resemblance of its scutes, in their concentric striation with those of tortoises.

The normal or rounded portion of the rib begins to project from the under surface of the expanded plate at two inches distance from the head of the rib; but the superincumbent expanded portions and their sutures are continued as far as the marginal plates; as in other full-grown *Emydes*.

Emys testudiniformis, nob.
Emys de Sheppey, Cuv.?

Most of the *Chelonites* from the Eocene clay of Sheppey belong to the marine family* of the order, from which the present species differs in the depth of the bony cuirass, the convexity of the carapace, the concavity of the plastron, and the extent of ossification of both these parts. The more immediate affinities of the present fossil are elucidated by the comparison of the points of structure which it displays with the anatomical characters of the carapace of the *Emys* and *Testudo*.

The specimen, on which the species *Emys testudiniformis* is founded, includes a large proportion of the first, second, third, fourth, fifth and sixth, with a fragment of the seventh expanded vertebral ribs of the left side; a small proportion of the second, third, fourth, fifth and sixth vertebral plates; the hyo- and hyposternals, and part of the entosternal bones of the plastron.

The first rib is 1 inch 10 lines, in greatest breadth; 1 inch 5 lines broad at its junction with the vertebral plates, and four-fifths of the vertebral margin is articulated with the second vertebral plate; one-fifth part, divided by an angle from the preceding, joins a corresponding side of the lateral angle of the third vertebral plate; in this structure it resembles both the genus *Testudo* and some species of *Emys*.

The third, fourth, fifth and sixth vertebral plates are of equal breadth as in *Emydes*; not alternately broad and narrow as in the *Testudines*: they are likewise of uniform figure, as in most *Emydes*; not variable, as in *Testudines*: the vertebral plates also resemble those of the existing *Emydes*, and particularly of the Box-terrapin (*Cistudo*) in form. The lateral margin of each is bounded by two lines, meeting at an open angle, the anterior line is only one-fourth part the length of the posterior one; and this resemblance may be stated with confidence, since the portion of the entosternal piece preserved in the plastron determines the anterior part of the fossil.

The ribs preserved in the present Chelonite differ from the corresponding ones of the Tortoises and resemble those of the *Emydes* in their regular breadth, and the uniform figure of the extremities articulated with the vertebral pieces; the anterior line of the angular extremity is nearly three times as long as the posterior one.

Further evidence of the relation of the present Chelonite to the freshwater family is given by the impressions of the epidermal scutes: those covering the vertebral plates (*scuta vertebralia*) agree with those of most *Emydians* in the very slight production of the angle at the middle of their lateral margins, which is bounded by a line running parallel with the axis of the carapace, except where it bends out to form that small angle.

The middle part of each side of the plastron, in the *Emys testudiniformis*, is joined to the carapace by a strong and uninterrupted bony wall, continued from a large proportion of the hyo- and hyposternal bones upwards to the marginal costal pieces. The median margin of the hyo- and hyposternals are articulated together by a linear suture, traversing the median line of the plastron, and only broken by a slight angle formed by the right hyposternal, which is a little larger than the left. A similar inequality is not unusual in both Tortoises and Emydes. The transverse suture is, of course, broken by the same inequality; that portion which runs between the left hyo- and hyposternals being two or three lines in advance of the one between the right hyo- and hyposternals. The posterior half of the broad entosternal piece is articulated to a semicircular emargination at the middle of the hyosternals; so that the whole plastron forms one continuous plate of bone. This is relatively thicker than in existing Emydes, resembling in its strength that of Tortoises; and it is likewise slightly concave in the middle, which structure is more common in Tortoises than in Emydians, save those in which the sternum is moveable; in most of the other species the sternum is flat or slightly convex.

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* See Proceedings of the Geological Society, Dec. 1, 1841.

I have shown in my paper on the Turtles of Sheppey*, that the carapace figured by Cuvier† was not sufficiently perfect to decide the affinities of the Chelonian to which it belonged; if the vertebral scutes were less broad and angular than in marine turtles, the vertebral plates—much less variable in their proportions—were, on the other hand, as narrow as in turtles. But with reference to the plastron of the Sheppey Chelonite, figured by Parkinson‡, and supposed by Cuvier to belong to an *Emys* of the same species as the carapace above alluded to, I have been able to determine, by an examination of the original specimen in the museum of Prof. Bell, that it belonged to the marine genus *Chelone* and to the species *longiceps*. In the fossil *Emys* in Mr. Bowerbank's collection, the plastron being in great part preserved, establishes its nonconformity with the marine turtles, and manifests a striking difference from Parkinson's fossil plastron.

The entosternal piece is impressed, as in Tortoises and Emydes, by a median longitudinal furrow; a transverse linear impression traverses the hyosternals half an inch behind the suture of the entosternal; the second transverse line is not so near the first as in Tortoises, but bears the same relation to the transverse suture of the plastron as in most Emydes; it does not pass straight across the plastron, but the right half inclines obliquely inward to a more posterior part of the median suture than is touched by the left half. The third transverse line passes straight across the plastron between the posterior ends of the bony lateral walls, uniting the carapace and plastron.

	In.	Lines.
The breadth of the plastron is	5	10
The outer posterior extent of the lateral wall is	3	9
The breadth of the entosternum	1	5
The depth of the whole bony cuirass at the middle line is	4	0

In the convexity of the carapace and relative depth of the osseous box the Sheppey Chelonite slightly surpasses most existing species, resembling in this respect the *Emys ocellata* and *Cistudo Carolina*. The plastron is also slightly concave, as in the male of *Cistudo vulgaris*: it is, however, entire at the line where the transverse joint of the plastron exists in the Box-tortoises; and the extent and firm ossification of the lateral supporting walls of the carapace forbid likewise a reference of the fossil to those genera. The general characters of the present fossil, more especially the uniformity of size and breadth of the preserved vertebral plates and ribs, prove it to be essentially related to the freshwater or Emydian Tortoises. It exceeded in size, however, almost all known Emydians, and was almost double the dimensions of the Emydian species (*Cistudo Europea*) now inhabiting central Europe. It appears, like the *Cistudines*, to have approached the form of the land-tortoises, in the convexity of the carapace, but without possessing that division and hinge of the plastron which peculiarly distinguishes the box-tortoises. In the thickness and strength of the bones of the buckler, especially of the sternum, we may discern an affinity to *Testudo*.

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* Geological Proceedings, December 1, 1841.

† Ossem. Foss., tom. v. part iv. pl. xv. fig. 12.

‡ Organic Remains, vol. iii. pl. xviii. fig. 2.

Assuming that the Chelonite here described may be identical with that of which the carapace from Mr. Crow's collection is figured in the 'Ossemens Fossiles[*],' the '*Emys de Sheppey*' of Cuvier will be one of the 'Synonyms' of the present species. Mr. Gray, in his 'Synopsis Reptilium,' has given Latin names to all the fossil reptiles indicated or established by Cuvier, and has called the 'Emys de Sheppey' '*Emys Parkinsonii*,' referring as representations of this species, not to the figure of the carapace above cited, which may belong to the same species as the present *Emys*, but to the figure of the plastron, copied by Cuvier from 'Parkinson's Organic Remains,' and to the figure of the skull in the same work, both of which most unquestionably belong to the genus *Chelone* and not to the genus *Emys*.

The '*Emys Parkinsonii*' of Mr. Gray is a synonym of my *Chelone longiceps*. Cuvier's name,—which, besides the claim of priority, is the honest result of labour devoted to the elucidation of its subject,—if rendered into Latin would be *Emys toliapicus*; but as the species to which it refers may not be the one here described, and is not the only freshwater tortoise which the clay of Sheppey has yielded; and since the characters of the present species have not, hitherto, been defined nor its affinities to the land-tortoises been pointed out, the interests of science, it appears to me, will be best consulted by naming the present species *Emys testudiniformis*.

The fossil here described is from the Eocene clay of Sheppey Island, and forms part of the collection of J. S. Bowerbank, Esq.

Platemys Bowerbankii, nob.—Another specimen from the same rich collection of Sheppey remains actually indicates a distinct species of the freshwater family of *Chelonia*, which from its more depressed figure, its size, and the general form of the sternum, most probably belonged to the *Platemydian* division of that family[†].

The sternum is 13 inches in length and 10 inches in breadth; it is broader before than behind, rounded in front, notched behind: the surface is nearly flat, slightly convex at the anterior part, and as slightly concave behind.

The lateral bony wall or ala uniting the plastron to the carapace is 5 inches in length or antero-posterior extent, and it commences 3 inches behind the anterior extremity of the plastron. The episternals meet in advance of the entosternal, the length of the suture joining their anterior extremities, being 7 lines: from the peripheral end of this suture to that of the suture between the episternal and hyosternal bones is 2 inches 6 lines: from the latter suture to the anterior concavity of the lateral wall is 5 lines. In a tortoise with a plastron 13 inches long, the length of the same suture was 1½ inch, and the suture between the episternal and hyosternal bones is nearer the lateral wall. The *Emydes*, especially *Emys* (*Platemys*) *depressa*, most resembles the fossil, especially in the more important character of the relative length of the lateral wall and suture.

The carapace presents the same conformation and regularity of size of the vertebral plates and ribs as in the *Emys testudiniformis*; but it is flat, even slightly concave along the middle tract; and has somewhat narrower vertebral plates, of which the third to the eighth may be distinguished in the fossil; the ninth being concealed by the union of the vertebral extremities of the 7th pair of expanded ribs.

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[*] Ed. 1824, vol. v. part ii. pl. xv. fig. 12.

[†] *Hydraspis*, Bell and Gray.

The vertebral plates are all smooth and flat; their dimensions are as follows:—

	In.	Lines.
Length of the fourth plate	1	11
Greatest breadth	1	3
Length of the fifth plate	1	8
Greatest breadth	1	3
Length of the sixth plate	1	6
Greatest breadth	1	3
Length of the seventh plate	1	1
Greatest breadth	1	3
Length of the eighth plate	0	9
Greatest breadth	1	0

In the circumstance of the vertebral plates in this fossil decreasing in length without losing breadth, as well as in the junction of the seventh pair of ribs, the present fossil resembles the Sheppey carapace from Mr. Crow's collection figured by Cuvier; which may, therefore, have belonged to the present species of *Platemys*.

Platemys Bullockii, nob.—A very fine plastron of a *Platemys* from Sheppey was obtained by the British Museum at the sale of Bullock's collection, which differs from the preceding in the finely punctate character of the external surface of the bone, and in the narrower notches between the body of the plastron and the lateral alæ or uniting wall. The following are dimensions of this specimen:—

	In.	Lines.
Length	16	6
Extreme breadth (anterior to lateral wall)	8	0
Breadth or transverse extent of lateral wall	2	6
Antero-posterior extent of lateral wall	5	6
Antero-posterior extent of carapace anterior to lateral wall	5	0
Antero-posterior extent of carapace posterior to lateral wall	6	0

The anterior contour of the sternum is rounded; the posterior termination is notched. The lateral wall extends horizontally, almost parallel with the plane of the sternum, and expands to join, by a wavy suture, the marginal plates; six of these are preserved on each side; their lower margins form a very open angle. The anterior part of the entosternum is bounded by two nearly straight lines, converging forwards at an angle of 65°, with the apex rounded off; the posterior contour of this bone is semicircular. The length of the entosternal is 2 inches 10 lines; its breadth 3 inches 7 lines.

The chief peculiarity of this plastron is the intercalation of a supernumerary piece of bone between the hyosternal and hyposternal elements, on each side; so that the plastron is crossed by two transverse sutures, instead of one; each suture being similarly interrupted in the middle by an angular deflection from the right, half an inch back, to the left side. The extremities of the transverse sutures terminate each at the apex formed by the inner or lower border of the parallel marginal plates. The first or anterior of these sutures is distant from the anterior margin of the plastron 6 inches 5 lines: the second suture is distant from the same margin 8 inches 9 lines: the right half of the suture, which is a few lines in advance of the left, is the part from which these measurements are taken.

It might be suspected that the transverse impressions of the second or third pairs of sternal scutes had here been mistaken for a suture; but due care was observed to avoid this error: the sternal scutes have left obvious impressions, which prove that they were in the same number as in the Platemydians generally, and quite distinct from the sutures in question.

Thus the first median scute is in the form of an ancient shield; its posterior apex impressing and crossing the anterior apex of the entosternum. The posterior transverse boundary of the succeeding pair of sternal scutes crosses the plastron 4½ inches from its anterior margin; that of the third pair of scutes crosses at 7½ inches from the anterior border, and between the two transverse sutures; that of the fourth pair at 10 inches distance from the anterior margin, and about 1¼ inch behind the second transverse suture; passing straight across the plastron between the posterior concave margins of the lateral walls. The posterior boundary of the fifth pair of scutes inclines obliquely backwards from the median line, as usual; it is 3 inches behind the preceding transverse impression.

It is in the interspace of these impressions that traces of the transverse suture between the hyposternals and xiphisternals are obvious, about 4 inches from the posterior extremity of the plastron. If these traces were not so obvious, it might be supposed that the xiphisternals were of unusual length, entering into the formation of the lateral wall, and extending backwards from the second transverse suture to the end of the plastron; but this disproportion would be hardly less anomalous than the existence of the additional pair of bones intercalated between the hyo- and hyposternals which this present fossil evidently displays.

In most of the existing large *Emydes* and *Platemydes*, the median transverse suture traverses the plastron a little behind the third pair of scutes, or across the fourth pair; so that the second transverse suture in the fossil has the analogous position, and accordingly has most right to be regarded as the normal boundary between the hyo- and hyposternals. One of the most distinctive characters of the present extinct *Platemys* is, therefore, the division of each hyosternal bone into two, the sternum consisting of eleven instead of nine pieces; if the very interesting anomaly which it displays be not an accidental or individual variety.

The chief difference in regard to the sternal scutes, is the addition of two small ones anteriorly, one on each side of the median anterior pair in the fossil.

The obtuse ridge which forms the angle between the carapace and plastron is preserved in the fossil.

Tretosternon punctatum, nob.—In the rich collection of fossil remains belonging to Sir P. Egerton, there is the posterior part of the carapace of a fine species of freshwater tortoise, which, by its broad and extremely flattened form and sculptured surface, is evidently closely allied to the genus *Trionyx*, but which, from the impressions of distinct horny scutes, is essentially related to the Emydian family, and is nearly allied to the genus *Platemys*, D. & B. (*Hydraspis*, Bell.): this portion of carapace contains the fifth to the twelfth vertebral plates inclusive, and the five posterior pairs of expanded vertebral ribs. The external surface of both elements of the carapace is closely pitted with minute irregular impressions, smaller than a pin's head, and along their sutural margins for the extent of two or three lines by straight and parallel linear impressions, at right angles or nearly so to those margins: the pin-head impressions are sparing or absent at these striated margins.

The breadth of the carapace, across the fourth pair of ribs, is 13½ inches: the length of the moiety of the carapace here preserved is 9 inches: the entire length would be, probably, 17 inches. The flattened ribs gradually expand towards their distal extremity.

The close resemblance which this species makes to the *Trionyces*, in the sculpturing of the external surface of the carapace, is very striking; but the impressions of the horny scutes, and the non-continuation of a narrow tooth-like portion of the rib from the distal end of the expanded part, are essential distinctions.

The entire and rounded terminal margins of the truncated and expanded extremities of the ribs, beyond which there is not the slightest trace of projecting tooth-like processes, strongly indicates that the marginal plates were either wanting or rudimental, as in the genus *Cryptopus*.

This fossil is from the Purbeck limestone.

In the collection of Mr. Bowerbank is preserved the left half of the plastron of the same species of freshwater tortoise, from the Purbeck limestone, at Swanage, equal in size and probably of the same species as the preceding, but with fainter impressions on the external surface. This Chelonite includes the hyosternal, the hyposternal, and a considerable part of the xiphisternal bones, but wants the extremity of this bone. It is a very remarkable and characteristic fossil, chiefly on account of the great extent of the lateral wall, which is continued outwards, in the same plane with the rest of the plastron, as in the Emydian subgenus *Platysternon*, Gray, accompanied by an unusual width of the notches, anterior and posterior to this wall, for the emergence of the fore and hind-feet. The length of this fossil, taken along the median suture, is 13 inches; the breadth of the sternum along the median transverse suture must have exceeded 12 inches. The antero-posterior extent of the contracted part of the lateral wall is 7 inches; that of its expanded outermost part 9 inches; the antero-posterior diameter of the hyposternal bone 4 inches 4 lines; extent of transverse suture between this and the xiphisternal 3 inches. The outer and anterior angle of the xiphisternal has a shallow angular notch which receives a corresponding process of the hyposternal: the median margin of the hyposternal has a semicircular piece cut out of it just where it joins the hyosternal: the bone gradually narrows off to the edge of this emargination, which is exposed, by a careful removal of the matrix, without any trace of fracture of the bone. If it be, as it seems, a natural structure, then the centre of the sternum must have presented an elliptical vacuity, closed by membrane or cartilage of nearly two inches diameter, situated immediately behind the transverse suture uniting the hyo- and hyposternals. Such an approximation to the *Trionyces* and *Chelones* presented by an extinct species, which from the extensive lateral union by a continuous bony plate of the side of the plastron with the carapace, and from the complete ossification of the latter is essentially an Emydian species, forms a very interesting transitional modification, especially if it be combined, as there seems good reason to believe, with the sculptured surface of a remarkably flattened carapace, such as the Chelonite, in Sir P. Egerton's collection, from the same stratum and locality presents.

The sternum, like the carapace above mentioned, is impressed by the margins of distinct scutes.

The transverse line bounding the second sternal scute has the same relative position as in the *Testudo Schweigeri* and *Platemys planiceps*. The two succeeding sternal scutes have a more equal antero-posterior extent than in those species. The impression commences at the median line, nearly an inch in advance of the transverse suture and three inches behind the second transverse scute, and describes a slight curve which is convex towards the anterior part of the plastron. The third scutal line commences from the middle of the median emargination, and instead of running parallel with the preceding line, as in the Tortoises and ordinary Emydes which I have examined, it inclines backwards as it passes outwards, and terminates at the middle of the posterior lateral emargination. The fifth scutal line is oblique, as in the Emydians generally, and here therefore runs parallel with the fourth line at a distance of three inches and a half from it. The line bounding the lower part of the marginal scutes, which in Tortoises is either parallel with or a little above the suture uniting the lateral wall of the plastron with the marginal plates, here intersects the marginal wall of the plastron at a distance of from two-thirds of an inch to one inch and a half from that margin: impressions of four of the marginal scutes may thus be traced upon this part of the sternum, a structure in which the present fossil differs most remarkably from all known existing Tortoises. This difference it is the more necessary to bear in mind, since, in the antero-posterior extent as well as the transverse extent of the lateral wall of the sternum, and in the form and extent of the emarginations which bound the anterior and posterior part of this wall, the present fossil exhibits a closer resemblance with the Land-tortoises than with the ordinary *Emydes*. But the external surface of the plastron, instead of being slightly concave, as in most tortoises, is slightly convex; and where the plastron is convex externally in existing tortoises, namely, at the outer margin of the lateral wall, the fossil exhibits a slight concavity. In short, the character of the surface is such as would lead one having in his mind the plastron of a Tortoise as the ground of comparison, to suppose, at the first sight of the fossil, that he was looking on the inner side of the plastron; but the distinct and well-marked impressions of the epidermal scutes proves that it is actually the outer surface of the plastron which is here exposed. The anterior margin of the plastron is truncated, as in most Platemydians.

The osseous basis of the present plastron is half an inch in thickness; the structure of the bone is compact at the surface, including a coarsely spongy diploë, as in the Chelonians generally.

Portions of ribs of the *Tretosternon punctatum**, which from their specific punctation and sculpturing of the outer surface have been referred to the genus *Trionyx*, have been discovered by Dr. Mantell in the Wealden of Tilgate.

Amongst recent Emydians an approach to the *Trionyces* is made by the subgenus *Cryptopus* (*Emyda* of Gray), inasmuch as the marginal plates, especially of the posterior free margin of the carapace, exist in a rudimental or abortive state, as small granulated ossicles, suspended in the integument covering that border.

The subgenus *Chelydra* manifests its affinity to *Trionyx* by another modification of its osseous structure, viz. the absence of the lateral osseous walls, or alæ joining the plastron to the carapace, which are united only by flexible cartilage, throughout life.

No known existing species of Emydian has a free unossified central space in the sternum in the full-grown state; but this is an immature character common to all Chelonians, and is persistent in marine Turtles and *Trionyces*.

In the present highly interesting extinct genus, *Tretosternon*, it would appear that the absence of marginal plates, and a cartilaginous union of the plastron with the carapace, were associated likewise with a small vacuity in the middle of the sternum of the mature animal. The evidently feebly-developed scutes, and the sculpturing of the external surface of the flattened carapace, complete the last step in the transition from the Elodite to the Potamite families of Chelonians in the system of MM. Dumeril and Bibron.

Platemys Mantelli, Emys de Sussex, Cuv., *Emys Mantelli*, Gray.—The fossils discovered by Dr. Mantell in the Wealden strata of Tilgate Forest, and the resemblance of which to the flat species of Emydian discovered by M. Hugi in the Jura limestone at Soleure has been pointed out by Cuvier, are referable to the Pleuroderal section of the Emydian family, as arranged by

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* Illustrations of the Geology of Sussex, 4to, pl. vi. figs. 1, 3 & 5.

Messrs. Dumeril and Bibron*, and, in that section, to the genus *Platemys*: not enough of the skeleton of any individual has yet been obtained to afford a foundation for a specific character.

Large Emydian from the Kimmeridge Clay.—In the museum of Sir P. Grey Egerton is preserved the pubic bone of a large Emydian tortoise, obtained from Heddington Pits. The bone measures 4½ inches in length, and 2 inches 10 lines in the breadth of the symphysial plate. As its specific deviations, particularly in regard to the length of the sternal process, from the pubis of ordinary Emydians are well marked, it may probably belong to a species of *Platemys*.

Footsteps of Emydians in New Red Sandstone.—Among the numerous footsteps of Reptiles impressed upon the sandstone of Stourton Quarries, Cheshire, those of an Emydian Tortoise of moderate size are not uncommon.

Genus *Trionyx*.

Certain British fossils from the secondary formations, referred to *Trionyx*, have been proved to belong either to another family of Chelonians, or to a distinct class of animals. We learn from Dr. Buckland, that the supposed *Trionyx* from the new red sandstone at Caithness (Caithness slate), has been pronounced by M. Agassiz to be part of a fish: it is referable to the ganoid genus *Coccosteus*.

I have as yet seen no Chelonite from the Wealden freshwater formations that can be confidently affirmed to belong to *Trionyx*. The specimen described and figured in the 'Illustrations of the Geology of Sussex,' 4to, p. 60, pl. vi. fig. 8, is the dermal scute of the Crocodilian genus *Goniopholis*, as Dr. Mantell himself has subsequently recognized: the other portions (pl. vi. figs. 1, 3, 5) belong, as already observed, to the *Tretosternon punctatum*, a species which, like the *Goniopholis*, is common to the Wealden of Tilgate and the Purbeck limestone.

Femur from lias at Linksfield.—I have been favoured by Mr. Robertson of Elgin, with the examination of a Chelonian femur, 4½ inches in length, from a stratum at Linksfield, in which remains of *Plesiosaurus* and *Hybodus* occur; and this femur, though not identical in form with that of any *Trionyx* with which I could compare it, yet resembles the modifications of the bone in that genus more closely than in Tortoises, Emydians or Turtles.

Although some of the turtles of the Eocene period, as the *Chelone longiceps*, present such modifications of the jaws as seem to have adapted them to habits and food analogous to those of the *Trionyx*, yet evidences of this genus, to which the destruction of the eggs and young of Crocodiles is more particularly assigned in the Nile and Ganges, are not wanting in certain localities where the London clay appears to have been deposited under circumstances analogous to those at the termination of equally gigantic rivers.

Unequivocal portions of a true *Trionyx* have been obtained from the Eocene clay at Sheppey, and at Bracklesham; they are also associated, as in the Paris basin, with remains of *Anoplotherium* and *Palæotherium* in the Eocene lacustrine deposits of the quarries at Benstead in the Isle of Wight.

Family CHELONIDÆ, Thalassian† family, or Turtles.

Genus *Chelone*.

Chelone planiceps, nob.—The oldest British geological formation from which fossil remains, clearly referable to the marine genus *Chelone*, have hitherto been found, is the Portland sandstone.

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* Erpétologie, 8vo, 1835, tom. ii. pp. 172, 372.

† "Cheloniens Thalassites," Dumeril and Bibron, *l. c.*, p. 506. The unfortunate similarity of the generic name of the marine Chelonians, viz. *Chelone*, with the name of the order, *Chelonia*, renders the term 'thalassian' convenient, in allusion to the peculiarities of the marine species or 'Turtles.'

Prof. Buckland possesses portions of the carapace and a beautiful specimen of the skull of a Chelonian from the Portland sandstone, which, in the large size of the orbits, the breadth but otherwise small size of the external nostril, the extent of the osseous plate covering the temporal fossæ, and formed principally by the expanded posterior frontal and parietal bones, presents unequivocal characters of a marine species. It differs, however, from all other known recent and most extinct Turtles, in having the cranium more depressed, the nasal bones divided by a distinct transverse suture from the pre-frontals, and by some other minor differences, in which an affinity to the Platemydian family may be traced. The length of this cranium is 4 inches 4 lines, its greatest breadth 4 inches. The chief modification of external form is the deep emargination of the lower border of the cranium, between the malar and tympanic bones; a character by which the present species approaches *Emys* and *Testudo*. The *Chelone longiceps* of the Eocene tertiary formations makes a similar but less marked approach to *Emys*; and the present Turtle also resembles *Chel. longiceps** in the form of the mastoid bone, which, instead of forming a thick convexity behind the wide tympanic cavity, forms a smooth and slightly concave, moderately broad, semicircular plate of bone. The muzzle is, however, as short in the Turtle of the Portland stone as in ordinary species of *Chelone*; the distance, for example, from the anterior part of the orbit to the end of the muzzle, is only 11 lines. The median frontal sends a narrow pointed process forwards between the pre-frontals, as far as the suture which divides them from the nasal bones. The breadth of the interorbital space is relatively less than in recent Turtles, or than in the *Chelone longiceps*: it measures 8 lines.

The median frontal enters into the formation of the upper part of the orbit, in a greater proportion than in *Chel. mydas*: in the *Chel. imbricata* it is excluded by the union of the post-frontal and pre-frontal bones. The outer surface of the skull is rather undulated, marked with fine striæ and punctures, but not rugous, as in *Chel. breviceps*†; the nasal bones are convex, and impressed with larger pits. The upper boundary of the nasal aperture is straight, the lateral ones curve to a point below: the breadth of this aperture is 7 lines; that of the orbit is 13 lines.

The nasal process of the superior maxillary is characterised by a slightly raised rough portion.

The lower jaw closely conforms to the ordinary Thalassian type; the symphysis is convex, oblique, and as short as usual; there is no approximation to the peculiar condition of this part in the Harwich Turtle (*Chel. planimentum*‡).

The suture between the supra-angular and dentary piece does not make so long and sharp an angle forwards, as in the *Chelones mydas* and *Caretta*; the coronoid process is rather higher, and the dentary piece sends out a ridge which seems to have bounded the insertion of the temporal muscle below.

Thus the present cranium offers ample proof of its specific distinction from that of any previously described *Chelone*; and, while it has all the essential characters of that marine genus, exhibits some points of resemblance to the Emydians, as in the minor breadth of the interorbital space, the deep concavity of the lower border of the skull behind the orbit, and in the form of the mastoid bone. The separate nasal bone, which is the most interesting structure in the present skull, though hitherto unknown in the genus *Chelone*, has been met with in the Platemydian subgenus, *Chelodina*, the cranium of which, in other respects, closely conforms to the ordinary Emydian type, and has not the temporal fossæ protected by bone, as in the *Emys* (*Podocnemis*) *expansa**.

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* See Proceedings of the Geological Society, December 1st, 1841.

† Ibid.

‡ Ibid.

Chelone obovata, nob.—The most complete and beautiful specimen of a fossil turtle, from secondary strata, that I have yet seen, is one from the estuary limestone formation of the Isle of Purbeck, in the Collection of Channing Pearce, Esq. of Bradford, Wiltshire.

This species differs from the *Chelone Benstedi* of the chalk, from the Glaris Turtle, and from all the well-determined Eocene species in the form of the carapace, which, although obtusely pointed behind, begins to contract to that extremity only at its posterior third part; it gradually widens through the two anterior thirds of its extent, and is broadest at the junction of the fifth and sixth ribs; the contour being obversely ovate, or with the broader end turned downwards. This modification of form arises, not from the superior length of the fifth and sixth pairs of ribs, but from the breadth of their sternal appendages, called marginal plates. The internal surface of the carapace is exposed to view, and is shallower than in any other *Chelone*; resembling in this character the *Trionyx* and *Tretosternon*; the margins of the carapace are slightly bent upwards, as in some *Emydes*.

The first vertebral plate is shorter antero-posteriorly, and less deeply emarginate anteriorly than in the Maestricht *Chelone*†, and the first pair of expanded ribs is narrower. This well-marked difference fortunately occurs in the only parts in which a comparison could be established with the Turtles from a stratum so nearly contemporaneous with the Purbeck beds. The first rib is straight, and rather narrower in proportion than in the Eocene Turtles; in *Chelone mydas* this rib is the broadest of the series. It very gradually contracts into its dentiform extremity, which on the left side appears to have been separated by a narrow membranous space from the anterior marginal plates, but not on the right side. The second rib is broader in proportion to the first than in any other species of *Chelone*, recent or extinct; more so even than in the *Trionyx*, in which the first rib is narrower than the second. The third and fourth ribs are the broadest.

	In.	Lin.
The length of the expanded part of the fourth rib is .	3	0
The breadth of the expanded part of the fourth rib .	1	5
The length of the dentiform extremity	1	0

The rest gradually diminish in length and breadth. They are all as flat upon the under surface as in *Chelone mydas*, presenting a great contrast to the Harwich species, *Chel. planimentum*, in this respect.

The median row of vertebral plates, after the first, are as narrow as in most *Chelones*, and appear, as far as their form can be traced from an inside view, to resemble those of the *Chel. mydas* and *Chel. longiceps*, but to have been narrower than in the extinct Eocene Turtles: the length of the fourth vertebral plate in the *Chel. obovata*, for example, is 1 inch 3 lines, its greatest breadth is 6 lines. The eleventh six-sided plate, which resembles a triangle, with truncated angles, and is wedged between the last pair of ribs, is here divided by a transverse suture into two nearly equal parts. The twelfth plate is nearly twice as broad as long, and has convex lateral margins: the thirteenth vertebral plate, or the last of the marginal plates, is relatively broader than in existing turtles, and has its posterior margin more feebly emarginate. The marginal plates differ in the superior expanse of those attached to the fifth, sixth and seventh ribs. That to which the eighth rib is attached corresponds with the tenth in the *Chel. mydas*, and the eleventh projects in an angular form into the interspace between the dentiform extremity of the eighth rib and the twelfth vertebral plate. The thirteenth marginal plate sends a similar process between the seventh and eighth ribs: the exterior margins of all the marginal plates are straight, and the carapace is bounded by an unbroken contour. The diameter of the marginal plate attached to the fifth rib, parallel with the axis of the carapace, is 1 inch 6 lines; the diameter transverse to the carapace is 6 lines:

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* The different proportions in which the cranial bones, especially the post-frontals, enter into the formation of the bony covering of the temporal fossæ in the *Emys expansa*, serve to distinguish the skull of a *Chelone* from that of this exceptional example of an Emydian with the temporal fossæ covered by bone.

† Cuv. Ossem. Foss., tom. v. pt. 2. pl. xiv. Tortues, fig. 1 and 2.

	In.	Lin.
The length of the carapace	10	9
The breadth of the carapace	9	6

A considerable proportion of the plastron of the same individual is preserved, together with part of the bones of the hinder extremities, and both afford essential characters of the genus *Chelone*. The plastron of the *Chelone obovata* resembles that of the Eocene Turtles in the greater extent of ossification, and especially in the greater breadth of the xiphisternals, as compared with the recent species; but it differs from all other known species of *Chelone* in the greater depth of the notches at the anterior part of the hyosternals and at the posterior part of the hyposternals, which notches correspond with those that in the more fully ossified plastrons of *Emydes* give passage to the four locomotive extremities. The essential condition, however, of the plastron of the marine turtles is preserved, first, in the defective ossification of the lateral margins of the plastron between the hyo- and hyposternals, which are not co-extended and united to form a lateral wall of support to the carapace, as in the *Emydes*; and, secondly, in the form, and union by gomphosis, of the xiphisternals with the hyposternals: what proportion of the central part of the plastron continued unossified, the condition of the specimen does not allow of determining. There is evidence of the concavity of the sternum along the middle of the under surface, as in most *Chelones*.

The hyosternal is chiefly remarkable for the sudden expansion of the external radiated process, which occasions a notch at its posterior part, at the lateral unossified interspace between the hyo- and hyposternal bones, almost as deep as that which is anterior to the radiated process. The hyposternal bone presents likewise a similar modification of form. By this peculiarity of form the present species might be known by a single detached hyosternal or hyposternal bone. The tooth-like process of the hyosternal, which is implanted in the xiphisternal, is received into a notch, the inner boundary of which is much deeper than the outer.

The breadth of both the xiphisternals, taken across the termination of this notch, is 3 inches: they are separated by an angular fissure for the extent of an inch at their posterior interspace, but their median dentated margins meet in the rest of their extent, which is about one inch and a half.

The breadth of sternum, across the hyposternal bones, is 8 inches; the least antero-posterior extent of the conjoined hyo- and hyposternals is 4½ inches.

In this admeasurement, as compared with the transverse extent of the same bones, the *Chelone obovata* differs in a marked degree from the *Chel. longiceps* of Sheppey, and indeed approaches nearer to the existing species of *Chelone* than do the Eocene Turtles. The adherence to the thalassian type is likewise well exhibited in the present fossil by the forms and proportions of the principal bones of the hind-extremities or paddles, which are much shorter as compared with the fore-paddles and the body generally, in the marine than in any of the freshwater or land *Chelonia*. The length of the femur is 1 inch 9 lines; that of the tibia 1 inch 7 lines. The articular extremities are too imperfect to allow of a comparison of the forms of these bones with the corresponding ones of existing species.

Since the carapace of the *Chelone obovata* approaches, in those modifications by which it differs from other turtles, to the Emydian type, it is not improbable that the skull of the Chelonian, above described, from the contiguous subjacent stratum of Portland stone, which offers analogous approximations to the Emydian group, may belong to the same species.

Wealden Chelone, sp. indeterm.—Portions of the carapace and plastron, and bones of the extremities of a large species of marine turtle, some of them indicating individuals with a carapace nearly three feet in length, have been discovered by Dr. Mantell in the Wealden strata of Tilgate Forest, and are figured in his valuable 'Illustrations of the Geology of Sussex.'

No specific characters are deduced from these fossils, and the nature of the specimens seems not to have allowed the approximation to be carried closer than to the marine genus *Chelone*. With regard to one of the specimens, (pl. vi. fig. 2.) however, Mr. Clift's authority is quoted for its resemblance with the corresponding part of *Chelone imbricata*, and Dr. Mantell acknowledges that "as Cuvier had referred the turtles of Melsbroeck to the *Emydes*, we at first entertained doubts whether our appropriation of this specimen to the *Cheloniæ* were correct. Mr. Clift's remark, however, tends to confirm the opinion that it belongs to a marine turtle," *loc. cit.*, p. 62.

After a careful comparison of the specimens in the Mantellian Collection* in the British Museum, I have come to the conclusion that the Wealden species differs from *Chelone imbricata*, *Ch. carinata*, and other known species in as great a degree as do many of the other extinct *Chelones*, in regard to the greater extent of the ossification of the costal interspaces and of the sternum.

In the convexity of the under side of the vertebral ribs; and in the modifications of the form of the episternal, hyosternal and hyposternal bones the Wealden species offers the nearest resemblance to the *Chelone planimentum* of the Harwich Eocene clay. It is to be regretted that this relationship cannot be more decisively tested by a comparison of the skulls, and especially of the lower jaw of the two species: but these parts of the skeleton appear not to have been as yet discovered in the Wealden.

Chelone pulchriceps, nob.—The cranial anatomy of a fossil turtle from the superincumbent beds of lower greensand differs from that of other known species, but presents the nearest resemblance to that of the turtle from the Portland stone.

A small cranium of the present species of *Chelone*, from the greensand near Barnwell, Cambridge, in the museum of the Rev. Thomas Image of Whepstead, in the same county, is depressed, and likewise has the nasal bones marked off by a suture from the anterior frontals, but in a different manner from that in the skull of the Portland turtle. The characters of the genus *Chelone* are clearly expressed by the extensive roof of bone overarching the temporal fossæ, and by as large a proportion of this roof being formed by the post-frontals as in existing *Chelones*. The orbits are also large, and their superior interspace is broad.

The median frontals form a small proportion of the upper border of the orbits; the anterior extremities of the median frontals, instead of converging to a point, are extended forwards, between the anterior frontals, in a broader proportion than in the Portland Turtle, and are obliquely truncated: it is only in the genus *Chelys* among existing Chelonians, that the anterior frontals are thus separated from each other; but in the *Chelys* the intervening extremities of the median frontals are continued to the upper border of the external nostril. In the present fossil cranium the oblique extremities of the anterior frontals are arrested at the distance of four lines from the nasal aperture, which is bounded above by two distinct nasal bones; these bones are joined by suture to the median frontals, to the anterior frontals, and to the superior maxillaries; the nasal processes of which extend upward, and exclude the anterior frontals from the nasal boundary. The superior maxillaries are traversed obliquely by a large and deep scutal impression, above which the superior maxillary forms a convex prominence at the anterior part of the orbit. The scutal groove which traverses the median frontals is as strongly marked; that which impresses the post-frontals is fainter. The expanded trumpet-shaped portion of the tympanic bone comes nearer the upper margin of the cavity than in existing *Chelones.*

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* No. 2338, "Sternal plate of a marine turtle," *MS. Catalogue of Mantellian Museum*, now in the British Museum, is unquestionably the left hyposternal, and part of the lateral wall, supporting the carapace of a Tortoise or Emys.

The palatal bones have no true palatal process. The palatal processes of the intermaxillary and maxillary bones form an unusually prominent angular ridge, running nearly parallel with the trenchant margin of the jaw: the bony palate is not extended along the middle line beyond the intermaxillaries. The pterygoid bones present moderately wide and deep external emarginations.

	In.	Lin.
Length of the cranium from the occipital tubercle .	2	3
Breadth of the cranium above the tympanic cavities .	1	6
Depth of the cranium at the parietal bones	1	0
Antero-posterior diameter of the orbit	0	10
Breadth of the interorbital space	0	8

Chelone Benstedi, nob.
Emys Benstedi, Mantell.

Although very characteristic remains of Chelonian reptiles have been determined by Cuvier, from the cretaceous beds of St. Peter's Mount, near Maestricht, no evidence of the present order of Reptiles in British chalk formations had been made public until my description of a Chelonite from the lower chalk at Burham, Kent, in the museum of Sir P. Egerton, appeared in the Proceedings of the Geological Society. This Chelonite consisted of four marginal plates of the carapace, and a few other obscure fragments, sufficient to prove that the species was not *Trionyx* or *Testudo*: and as they differed in form from those of the recent species of *Chelone*, with which I compared them, and resembled rather the posterior marginal plates of some Emydians, I stated that this correspondence "rendered it probable that these remains are referable to that family of Chelonia which lives in fresh water or estuaries." Subsequent observation of the various interesting modifications by which extinct *Chelones* diminish, as it were, the gap between the marine and freshwater genera as they remain at the present day, has weakened the impression which the character of the marginal plates of the chalk Chelonite first made in favour of its Emydian affinities; and the examination of the beautiful Chelonite, obtained from the same quarries at Burham, and relieved from the chalk matrix by Mr. Bensted, lately described and figured by Dr. Mantell in the Philosophical Transactions, has demonstrated that it is not an *Emys* but a true *Chelone.*

The fossil in question consists of nearly the whole carapace, and a considerable portion of the plastron, with a coracoid bone.

The carapace includes all the dorsal or vertebral plates, save the first; the usual number of expanded ribs, viz. eight pairs; and the entire border of marginal plates, save the three first. In the sternum the hyosternal and hyposternal bones may be distinguished. The general form of the carapace is elliptical, terminated by a point at the narrower posterior end, which, however, is less contracted than in other *Chelones*. It is as depressed as in *Chelones* generally. To judge from the unmutilated vertebral plates, which are the four last, the carapace appears to have been traversed by a median longitudinal crest, from which the sides gently slope with a slight convex curvature, as in *Chelone mydas*.

The more immediate indications of the close affinity of the fossil to the marine turtles are given by the incomplete ossification and anchylosis of the ribs and sternal bones, the latter being in consequence dislocated from each other; and more especially by the shape and size of the marginal plates attached to the third, fourth, fifth, and sixth ribs, as also by the form and length of the coracoid bone.

The vertebral plates are as narrow relatively as in the ordinary *Chelones*; but their precise form can only be distinguished in the three last. The ninth*, or that to which the eighth rib is in part articulated, is 3 lines in length and 2 in breadth; the tenth expands posteriorly into a triangular form; both these have their middle part raised into a ridge; the eleventh plate is suddenly expanded, with angular sides, which slope away from a median longitudinal ridge: this is crossed by a transverse ridge just anterior to the junction of the plate with the median terminal plate of the marginal series, which is convex above and traversed by a median longitudinal furrow. The margins of this plate meet posteriorly at an open angle. The second to the seventh pairs of expanded ribs are joined together only along their vertebral halves. The length of the expanded part of the third rib is 9 lines; its narrow, tooth-like part, before it reaches the marginal plate, is also 9 lines; about 3 lines of its extremity is inserted into the deep groove of the concave surface of the marginal plate. The width of the interspace between the narrow parts of the third and fourth ribs is 4 lines; the length of the expanded part of the first rib is 10½ lines; the breadth of the expanded part of the first rib is 8 lines; the length of the narrow end of the rib, clear of the marginal plate, is 3 lines. In the superior breadth of the first rib the *Chelone Benstedi* agrees with existing turtles, and differs strikingly from the Purbeck species. The last short rib sends, almost directly backwards, a short, narrow, tooth-like process, at right angles to the anterior margin of its sub-triangular expanded part. In *Chelone obovata* it is extended more nearly parallel with the expanded part.

The marginal plates have the same general uniformity of size which we observe in the existing *Chelones*; the posterior ones are not expanded as in the Purbeck *Chelone*, and in certain *Emydes*, as *Emys serrata*, &c.; but the most decisive evidence against the Emydian affinities of the present fossil is afforded by the form and development of the inferior borders of the marginal plates attached to the fourth, fifth, and sixth ribs; for these plates, instead of being expanded and extended inwards to join the hyo- and hyposternals, and to combine with these elements of the plastron in forming the lateral supporting wall of the carapace, are not so much developed in breadth as the same parts of the posterior marginal plates, but form with them an even free border, as in other *Chelones*, in which not any of the marginal plates are joined with the sternum.

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* In all *Emydes* the proportions of this plate are the reverse of those in the fossil.

With reference to the general imperfect ossification of the carapace, the deductions in favour of the marine nature of the Chalk Chelonite might be invalidated by the hypothesis that it was the young of some very large species of *Emys*; but the existing Emydians, at the immature period when they exhibit the incomplete ossification of the carapace and plastron, have the marginal plates opposite the lateral processes of the hyosternals and hyposternals joined with those processes by an inward development of their inferior border, which is suddenly and considerably broader than the inferior border of the contiguous free marginal plates. The outer contour of the ninth, tenth, and eleventh plates projects in the form of a slight angle, and thus differs from the same parts of *Chelone mydas* and *Chelone obovata*; the others have a straight free margin. The marginal plates appear as if bent upon themselves to form their outer margin, at a rather acute angle, receiving the extremities of the rib in a depression excavated in the concavity of the angle; they are nearly twice as long in the direction parallel with the margin of the carapace than transverse to it, and are traversed in the latter direction along the middle of their upper surface with the groove or impression of the marginal scutes. The free edge of the upper plate of the marginal pieces is slightly notched above the insertion of the rib, and they correspond with those of the Chelonite from the Burham chalk-pit in the collection of Sir P. Egerton. The form of the median or vertebral scutes is only to be traced at the anterior part of the carapace, but their relative breadth and the outward extension of their lateral angles correspond, like the characters of the more enduring parts, with the type of structure of the marine turtles. The breadth of the first vertebral scute is 1 inch 8 lines, that of the second scute is 2 inches.

The coracoid bone varies in form so as to be very characteristic of the different genera of Chelonians; it is a triangular plate in *Testudo*, a more elongated triangle in *Chelys*, a broad bent elongated plate in *Trionyx*, a narrower bent plate in *Emys*, a long, straight, slender bone, slightly expanded and flattened at the sternal end, in *Chelone*: now it is precisely the latter form that this bone, fortunately preserved in the present specimen, here exhibits, showing that the same modifications of the skeleton are combined in the past as in the present species of *Chelone*; it is 1 inch 7 lines in length, cylindrical at its humeral half, and gently expanded to a breadth of 3 lines at its sternal end. The proportion which this bone presents of one-fourth the length of the carapace is only paralleled in the existing *Chelones*; it is much shorter in the *Emydes*.

The hyosternal and hyposternal bones resemble rather those of the turtles than of the young Emydes; certainly no *Emys*, with a carapace 5 inches in length, presents such forms as these bones exhibit in the present fossil; several rays or pointed spines of bone are developed from the anterior half of the median margin of the hyosternal piece, as in *Chelone caretta*; the rest of the margin contributes to form the circumference of the large central aperture of the sternum. The hyposternal sends similar rays from the posterior half of its outer margin, leaving the anterior half to join, probably the same proportion of the outer margin of the hyosternal, so as to form a deep lateral angular notch of the sternum. The length of the hyposternal is 1 inch 2 lines. The epi-, ento- and xiphisternal bones are not preserved.

From the preceding description it must be obvious, as has been already observed, that the present Chelonite of the chalk can only be supposed to belong to the genus *Emys*, on the supposition that it is a very young specimen of some unusually large species: but against this supposition, the pointed form of the hind end of the carapace, the regularity of the size of the marginal plates, the non-development of the lower margin of any of these plates for a junction with the plastron, the narrow elongate form of the vertebral plates, and the broad vertebral scutes, collectively and separately militate; whilst in all these modifications the Turtle from the Chalk so closely corresponds with the true *Chelones*, that I cannot hesitate to refer it to the marine family of the order.

From the breadth of the xiphisternals in the remains of this species first described by me, I was induced to suppose that a new subgenus (*Cimochelys*) of marine Turtles was thereby indicated, having a closer affinity to the *Emydes* than the typical species; and the same affinity seems to be shown by the more regular elliptical form of the carapace of Mr. Bensted's beautiful specimen. The structure of the cranium, when this desirable part of the skeleton is discovered, may confirm the propriety of the subgeneric distinction; but the numerous decided marks of closer affinity to *Chelone* leave no alternative than to regard the fossil species of the chalk as a member of that genus.

It differs from all known species, especially the sub-carinated species of Sheppey, in the form of the carapace, which is more truly elliptical than in any other species with which I am acquainted.

I have been favoured with the opportunity of inspecting portions of the skeleton of a large Chelonian obtained by Mrs. Smith, of Tonbridge Wells, from the lower chalk at Burham, Kent, and skilfully relieved from their mineral bed by that lady. The principal bones consist of two series, one containing five, the other four, of the marginal plates of the carapace, in natural connection, and from that part of the margin where they receive the extremities of the vertebral ribs. These marginal plates in *Chelone mydas* are three-sided, and have two terminal surfaces by which they are united, suturally, to one another: of the three free surfaces, the one, directed towards the interior of the body, is characterized by a deep depression for the reception of the tooth-like extremity of the rib; the two other (upper and under) surfaces meet at an angle, which is produced at certain parts to form the marginal dentations of the lateral and posterior parts of the carapace in that species of turtle, but is more open and obtuse in the marginal plates at the anterior part of the carapace. In the fossil the marginal plates have the general characters of those of the genus *Chelone*, but differ from those of the *Chelone mydas*, in being more concave on the central or perforated side, and they are also concave at the upper side, and in a slighter degree at the under side; these sides likewise meet at a more acute angle, and this angle is produced into a sharper and more continuous ridge: but this ridge subsides at one end of the series of five plates, and the upper and under sides gradually meet at a more open angle, which is rounded off in the first of the series. This plate, therefore, answers to the third marginal plate in the *Chelone mydas*, or that which receives the end of the first expanded vertebral rib; and the remainder, therefore, to the fourth, fifth, sixth, and seventh marginal plates: now these are precisely the marginal plates in the *Emys*, which have their inferior margins developed inwards and articulated by suture to the lateral wall of the carapace: but these margins not being so developed or terminated in the present fossil, but, on the contrary, being inferior to the upper margin in breadth*, and terminating like that margin in a blunted edge, prove the present Chelonite to belong, like the smaller Chelonite from the same chalk-pit already described, to the marine genus *Chelone*.

The following admeasurements will show the different proportions of the marginal plates of the present specimen as compared with the corresponding ones of a *Chelone mydas* of similar general size:—

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* The upper margin, which is distinguished by a slight notch where the costal groove leads to the pit, is broader than the lower one, in these plates of the *Chelone mydas*; but the difference is less than in the present fossil species.

	Fossil Chel.		*Chel. mydas.*	
	In.	Lin.	In.	Lin.
Length of the series of five plates in a straight line	7	3	8	2
Breadth of the upper surface of the third (fifth) .	1	1	0	10
Interspace of costal depressions	1	2	1	6

Thus the marginal plates of the chalk turtle, besides being more concave, are broader in proportion to their length, or antero-posterior diameter. In these respects they correspond with the form of the marginal plates in the *Chelone Benstedi*, and most probably belong to a larger and older specimen of the same species.

There are two other marginal plates imbedded in the same portion of chalk, with their upper, smooth, slightly concave surfaces exposed; and the toothed or sternal extremities of three of the vertebral ribs, which by their length and size also prove this specimen to be a turtle. One of these fragments of rib measures 5½ inches, and the expanded plates developed from each side of its upper surface are concave on their exterior surface, which is flat or slightly convex in *Chelone mydas*.

A separate portion of chalk from the same pit contains the scapula and its acromial branch or anchylosed clavicle, with the articular surface which joins with the coracoid and humerus. The angle at which the scapula and clavicle meet is more open in *Chelone* than in *Emys* or *Chelys*: the present specimen presents the same angle as in the Maestricht *Chelone* figured by Cuvier*, in which it is rather more open than in the recent species of turtle. A broad, thin, slightly concave plate of bone appears, by the radiation of the fine striæ at its under part, to represent the expanded parietal bone of the cranium.

The carapace of the turtle to which the fragments above described belonged, must have been nearly if not quite two feet in length.

Eocene Tertiary Chelones.—Although both the leading divisions of freshwater Chelonians are represented in the Eocene tertiary formations of Great Britain, the one by the *Emys testudiniformis*, the other by the *Platemys* or *Hydraspis Bullockii*, the Chelonian Reptiles from the London clay of Sheppey and Harwich are for the most part true turtles, or species of the genus *Chelone*. Already good evidence of at least five distinct species have been obtained from these localities, and it is probable that others remain to be discovered; they are generally of smaller size than the species which are now restricted to warmer or intertropical latitudes, and differ from those species, as well as from each other, by well-marked characters afforded by the skull, the carapace, and the plastron.

Chelone longiceps.—The most common species, *Chelone longiceps*†, is distinguished by very interesting modifications both of the cranium and osseous buckler, by which it approaches more nearly to the freshwater Chelonians than do any of the existing species of *Chelone*. In the prolongation of the conical rostrum and osseous palate, the skull of this species resembles that of a *Trionyx*, but the temporal fossæ are covered by a roof of bone having the characteristic anatomical structure of the true *Chelones*. The buckler is broader in proportion, and both carapace and plastron are more completely ossified than in recent turtles; thus both the hyosternals and hyposternals are broader than they are long; the xiphisternals are unusually broad. The tooth-like processes from the mesial margins of the hyo- and hyposternals are more numerous and smaller than in existing species, and interlock with each other, so that two margins of each of these bones are joined by suture, instead of one, as in almost all other turtles. Yet in the largest specimens of this species which I have seen, the centre of the sternum remains unossified, its sides ununited by bone with the carapace, and the external and part of the internal margins of its constituent bones preserve their separated tooth-like rays.

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* Ossem. Foss., tom. v. part ii. pl. xiv. fig. 5.

† The characters of this and the other species of *Chelone* from the London clay formation are detailed in my Memoir on that subject read before the Geological Society, Dec. 1, 1841.

The small specimen of which the plastron is figured by Parkinson and by Cuvier, belongs to the present species of *Chelone*; it is now preserved in the rich collection of Prof. Bell. In the same collection there is preserved a specimen of *Chelone longiceps*, the plastron of which is 8 inches in length and nearly 8 inches in breadth; in this specimen, which is the largest of the present species that I have seen, the central vacuity of the plastron and the toothed margins of many of the constituent bones remain. Three of the Chelonites in the museum of Sir P. Egerton, two in that of Mr. Bowerbank, one in that of Mr. Dixon, and one in the Hunterian Collection, belong to the *Chelone longiceps*. All these specimens are from the Isle of Sheppey.

Chelone planimentum, nob.—The species which, in the number of individuals representing it comes next in order after the *Chelone longiceps*, is characterized by a flat and unusually long symphysis of the lower jaw, but this is associated with a broad, high, and convex cranium, and with a muzzle not longer than in ordinary *Chelones*. The carapace is characterized by the strength of the ribs which traverse the whole of the under part of the expanded plates in the form of thick convex ridges.

All the specimens of this species that I have hitherto seen are from the Eocene clay of the eastern coast of Essex. A carapace in the British Museum measures 13 inches in length and 12 inches across the fourth pair of expanded ribs. A skull in the museum of Prof. Sedgwick, associated with a carapace and other parts of the skeleton of the same individual, and another skull in that of Prof. Bell, indicate that the head was relatively as large in the *Chelone planimentum* as in the *Chelone imbricata*.

Chelone breviceps, nob.—This species, in the narrow, ovate, and posteriorly pointed carapace, and in the less extensive ossification of the sternum, resembles more the recent *Chelones* than does the *Chelone longiceps*. Its cranium also preserves the ordinary form in its depth and in the shortness of its muzzle. The external surface of the cranium and osseous buckler is rugous. The angles by which the expanded ribs are wedged into the interspaces of the vertebral plates have equal or nearly equal sides. It appears to have exceeded the *Chelone longiceps* in size: a portion of the osseous buckler of a *Chelone breviceps*, with a carapace 16 inches in length, is preserved in the museum of Mr. Robertson, surgeon, at Chatham.

Smaller specimens of the *Chelone breviceps*, all from the Isle of Sheppey are preserved in the Hunterian Collection, in the museum of Prof. Bell, and in that of Mr. Bowerbank. Mr. Bowerbank's specimen exhibits the head in connection with the carapace and plastron, and is the most beautiful Chelonite, perhaps, that has yet been obtained from any formation.

Chelone convexa, nob.—The surface of the bony buckler of this species, like that of the *Chelone longiceps*, is smooth, but the forms of the constituent bones of the carapace and their degree of ossification differ considerably from those of a *Chelone longiceps* of the same size, and resemble those of *Chelone mydas*. The carapace is more convex than in the *preceding species* from Sheppey, and than in the existing *Chelones*, whence the specific name of the present extinct species. It is from the Isle of Sheppey.

Chelone subcristata, nob.—This species, also from the Isle of Sheppey, has the usual thalassian form of carapace, which is narrow, ovate, and contracted to a point behind, with a sternum resembling also existing *Chelones*, in the form and degree of ossification of its constituent pieces, and the slenderness of the xiphisternals. It may be distinguished from the *Chelone breviceps* by the smoothness of its carapace, the different form of the vertebral plates, and the development of a sharp ridge on the sixth and eighth vertebral plates.

The sole example of this species which has come under my observation is the osseous buckler, 9 inches in length and 6½ inches in breadth, in the museum of Mr. Bowerbank.

Chelone latiscutata, nob.—This species is founded on a nearly complete buckler of a turtle from Sheppey, measuring 3 inches in length, from the second to the seventh plate inclusive: it may be a variety, or the immature state of *Chelone longiceps*, but I have not yet had the opportunity of ascertaining to what extent the relative breadth of the vertebral scutes varies in individuals of different age of existing species of turtle. In the present case the vertebral scutes are nearly twice as broad in proportion to their length, as they are in the *Chelone longiceps*, or in any of the other well-marked species of Eocene turtles.

The indications of Chelonites from Eocene strata, in the works of Parkinson, Woodward and König, being unaccompanied by the anatomical deductions essential to the establishment of their true affinities, have been either misinterpreted or neglected; and except the citation of Woodward's *Chelone Harvicensis*, in M. H. v. Meyer's Compilation*, the existence in the London clay of fossil *Emydes* alone has been recognized in the latest summaries of the present branch of Palæontology†. These, therefore, could indicate but little difference between the present fauna and that of the Eocene period in regard to the Chelonian order. But the case assumes a very different aspect when we arrive at the conviction that the majority of Sheppey Chelonites belong to the marine genus *Chelone*, and reflect that the number of extinct Eocene turtles from that limited locality very nearly equals that of all the well-determined species of *Chelone* now known to exist. For notwithstanding the assiduous search of the naturalist-collector, and the attractions which the shell and flesh of turtles offer to the commercial voyager, the tropical seas, though so often traversed, have not as yet yielded more than five good species of *Chelone*; and of these only two, as *Chelone mydas* and *Chelone caretta*, are known to frequent the same locality. Now, whilst it is obvious that but a small proportion of the organized treasures of the vast deposit of petrified mud and clay which fills the London Basin have been brought to light, the results of the examination of fossil Chelonites evidently show that the ancient ocean of the Eocene epoch was more abundantly provided with turtles, and that these presented a greater variety of specific modifications than the same extent of ocean in any of the warmer parts of the earth at the present day.

The indications which the Sheppey turtles give, in conjunction with the other organic remains from the same depository, of the higher temperature that prevailed in the latitude in which they lived, cannot be overlooked; yet at the same time the conditions, which allow of the attainment of the size which the present tropical turtles often exhibit, would seem not to have been present in the time and place of existence of the extinct species of *Chelone* above enumerated; and again, the affinities to the freshwater forms which the skeleton of some of the Eocene *Chelones* exhibit, accord with the indications that they inhabited the estuary of a great river.

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* Palæologica, p. 104.

† See Cuvier, Ossem. Fossiles, ed. 1836, 8vo, tom. ix. p. 464; Buckland, Bridgewater Treatise, vol. i. p. 258; the recent comprehensive work on Erpetology, by MM. Dumeril and Bibron, tom. ii. p. 533; and Dr. Grant in the British Annual for 1839, p. 266.

Order OPHIDIA.

In the Appendix to the second 4to edition of the 'Ossemens Fossiles,' Cuvier remarks, "Les os de serpens sont encore plus rares, s'il est possible. Je n'en ai vu que des vertèbres des brèches osseuses de Cette, dont j'ai parlé à l'article de ces brèches, et une seule des terrains d'eau douce de l'île de Sheppey*."

The Ophidiolites from this formation have been the subject of a memoir by me, published in the sixth volume (second series) of the Geological Transactions, in which the best-preserved specimens in the collections of John Hunter and Mr. Bowerbank are described. The Hunterian Ophidiolites were referred by the Founder of the collection, in the original MS. Catalogue, to the Crocodile; some of those in the private collections I found ticketed "Vertebræ of Tortoise." All these specimens presented the general characteristics of the vertebræ of serpents, and resembled in structure as well as size those of the Constrictors (*Python* and *Boa*) more than those of the colubrine or poisonous families. Very recognizable differences are to be discerned in the Eocene fossil vertebræ as compared with the vertebræ of existing Pythons and Boæ; they are longer as compared with their height or breadth; the costal tubercle is placed lower down; the transverse process supporting the lower anterior articular process has a greater vertical extent, and the ridge continued from the lower anterior to the lower posterior oblique process is less developed; the oblique processes do not extend so far outwards, and the spinous process is higher, but has a less antero-posterior extent than in existing land-serpents. The middle of the posterior margin of the neurapophysis, opposite the external angle of the articular excavation or mortise, is produced backwards in the form of an angular plate. The inferior surface of the vertebra is not longitudinally carinated, as in some *Colubri*, but has a tubercle at the middle of the anterior part, as in the *Python*.

These differences justify the consideration of the Sheppey Ophidiolite as the representative of a distinct genus as well as species, for which I have proposed the name of *Palæophis toliapicus*.

The largest of the Ophidiolites in Mr. Bowerbank's collection exhibits a portion of the vertebral column suddenly bent upon itself, including about thirty vertebræ, and indicating the usual lateral flexibility of the spine. The Hunterian specimen also consists of a group of as many vertebræ more disjointed, and cemented, with a number of long and slender ribs, irregularly together by a mass of indurated clay. In the museum of Mr. Saull a few vertebræ, and a fragment of the skull of the same *Palæophis*, likewise from Sheppey, are preserved. The size of the vertebræ in the foregoing specimens corresponds with that of the vertebræ of a boa constrictor of 10 or 12 feet in length.

Vertebræ of a serpent agreeing in character with those of the London clay at Sheppey, but smaller, have been obtained by Mr. Colchester, from the sand of the Eocene formation underlying the Red Crag at Kyson or Kingston in Suffolk. These have also the small tubercle at the under and back part of the body of the vertebra, instead of the ridge, as in *Coluber* and *Naja*; and thus, like the larger vertebræ from Sheppey, they come nearer to the *Python*; but the bodies of these vertebræ are longer in proportion to their breadth, as in the Sheppey *Palæophis*. The tubercle for the rib is single; in *Naja* it is almost divided into two, the upper being convex, the lower moiety concave; in the *Python* the upper half of the tubercle is convex and the lower half concave, but the two facets are not marked off. In the *Palæophis*, of both Sheppey and Kyson, it is simply convex.

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* Tom. v. part ii. p. 526.

The most perfectly preserved, as well as the largest specimens of vertebræ of *Palæophis* which I have seen, are from the Eocene clay at Bracklesham, and are preserved in the select collection of Fr. Dixon, Esq. of Worthing. The serpent to which the largest of these vertebræ belonged must have been upwards of 20 feet in length.

Ophidian reptiles, of ten, twelve, and twenty feet in length, exist in the present day only in intertropical regions, and they for the most part prey on mammals and birds. If, therefore, direct evidence of species of both these warm-blooded classes in the London clay had not been obtained*, they might have been strongly suspected to have co-existed with serpents of such dimensions as those to which the vertebræ and ribs above mentioned belonged.

Order BATRACHIA.

Of this order of Reptiles, represented in the present Fauna of Great Britain by a few diminutive species of frogs, toads, and newts, the remains of some remarkable extinct members have been discovered in the New Red Sandstone of Warwickshire.

As the determination of these fragments has been the result of the examination, in part microscopical, of detached bones and fragments of bone and teeth, and since the Batrachian order, like most others at the confines of a great natural group, exhibits wide modifications of its typical structure, a few words may be expected touching the grounds for referring the fossils in question to the Batrachian order, especially since similar fossils in another country, specimens of the same species, have been regarded as parts of Saurians.

The Batrachians have no fixed type of external form like the higher orders of Reptiles, but some, as the broad and flat-bodied toads and frogs, most resemble the Chelonians, especially the soft-skinned mud-tortoises (*Trionyx*); other Batrachians, as the *Cæciliæ*, resemble Ophidians; a third group, as the Newts and Salamanders, represent the Lacertians; and among the Perennibranchiate reptiles there are species which combine with external gills the mutilated condition of the apodal fishes.

Thus it will be perceived, that, even if the entire skeleton of one of the New Red Sandstone Batrachians had been obtained, there is no fixed or characteristic general outward form in the Batrachian order whereby its affinity to that group could have been determined. The common characters by which the Batrachians, so diversified in other respects, are naturally associated into one group or suborder of reptiles, besides being taken from the condition of the circulating and generative systems and other perishable parts, are, however, fortunately as strongly manifested in modifications of the skeleton and principally in the skull. This is joined to the atlas by the medium of two tubercles, developed exclusively from the lateral occipitals; the bony palate is formed chiefly by two broad and flat bones, called 'vomerine' by Cuvier, and generally supporting teeth. It is only in the Batrachians among reptiles that examples are found of two or more rows of teeth on the same bone, especially on the lower jaw (*Cæciliæ*, *Sirenes*). With regard to vertebral characters, no such absolute Batrachian modifications can be adduced as those above cited from the anatomy of the cranium. Some Batrachians, as is well known, have the vertebræ united by ball-and-socket joints, as in most recent reptiles; others by biconcave joints, as in a few recent and most extinct Saurians. Some species have ribs, others want those appendages; the possession of ribs, therefore, even if longer than those of the *Cæciliæ*, by a fossil reptile combining all the essential Batrachian characters of the skull, would not be sufficient ground for pronouncing such reptile to be a Saurian. Much less could its Saurian nature be pronounced from the circumstance of its possessing large conical striated teeth; as the ordinary characters of size, form, number, and even presence or absence of teeth, varies much in existing Batrachians, the location of teeth on the vomerine bones being the only constant dental character in which they differ from all other orders of reptiles.

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* Geological Transactions, second series, vol. vi. p. 203, pl. 21.

My first acquaintance with the remarkable fossils under consideration was founded on the examination of portions of teeth, from the new red sandstone of Coton End quarry, Warwickshire, transmitted to me by Dr. Lloyd of Leamington. The external characters of these teeth corresponded with those which had previously been discovered, by Prof. Jaeger, in the German Keuper formation in Wirtemberg, and on which the genus *Mastodonsaurus* had been found.

The results of a microscopic examination of the teeth of the *Mastodonsaurus* from the German Keuper, and of those from the New Red Sandstone of Warwickshire, have been detailed in the Proceedings of the Geological Society, January 1841, and illustrated in my 'Odontography,' pp. 195—217, pls. 63, 63 A, 63 B, 64, 64 A, 64 B. They proved that the teeth from both localities possessed in common a very remarkable and complicated structure, to the principle of which, viz. the convergence of numerous inflected folds of the external layer of cement towards the pulp-cavity, a very slight approach was made in the fang of the tooth of the *Ichthyosaurus*, and that a closer approximation to the labyrinthine structure in question was made by the teeth of several species of fishes, while the teeth of existing Batrachians were simple, like those of most Saurians.

Thus, inasmuch as the extinct animal in question manifested in the intimate structure of its teeth an affinity to fishes, it might be expected that, if it actually belonged to the class of reptiles, the rest of its structure would manifest the characters of the lowest order, viz. the *Batrachia*, the existing members of which pass, though not by the dental character alluded to, yet by so many other remarkable degradations of structure, towards fishes. Now it has actually happened that, in the same formation in Wirtemberg from which the labyrinthic teeth of the so-called *Mastodonsaurus* have been derived, a fragment of the posterior portion of the skull has been obtained, showing the apparent absence of the basi-occipital, and the development of a separate condyle on each ex-occipital bone; whence Prof. Jaeger, recognizing the identity of this structure with the Batrachian character above mentioned, founded upon the fossil a new genus of *Batrachia*, which he called '*Salamandroides giganteus*.' Subsequent discoveries, however, satisfied the Professor that the bi-condylous fragment of skull, representing the genus *Salamandroides*, belonged to the same reptile as the teeth, on which he had founded the genus *Mastodonsaurus*. But notwithstanding the evidence thus obtained of the Batrachian affinities of the Keuper Reptile, Prof. Jaeger preferred to retain for it the name which implied its membership with the Saurian order, and cancelled the genus *Salamandroides*, which form of substantive has, indeed, been forbidden by the canons of botanical nomenclature to be used as the name of a genus*.

I proceed now briefly to notice the fossils from the Warwick sandstone described in my Memoir read before the Geological Society, and in which additional, and, as it seems to me, conclusive proof is given of the Batrachian nature of the genus to which those fossils belong; with the establishment of five distinct species, one of which is most probably identical with the *Mastodonsaurus salamandroides* of Prof. Jaeger.

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* "Nomina generica in *oïdes* desinentia e foro Botanico releganda sunt."—Linnæi Philosophia Botanica, 1751, p. 161.

It is scarcely necessary to repeat the reasons which I have given to show that the generic denomination *Mastodonsaurus* cannot be retained; first, it unavoidably recalls the idea of the mammalian genus *Mastodon*, or else a mammilloid form of tooth, whereas, all the teeth of the reptile so called are originally, and most of them are permanently of a cuspidate and not of a mammilloid form; secondly, because the second element of the word, *saurus*, indicates the genus to belong to the Saurian and not to the Batrachian order of reptiles. For these reasons I have proposed to designate the genus in question *Labyrinthodon*, in allusion to the peculiar and characteristic structure of the teeth.

The specimens which I have examined are referable to five species, viz. 1. *Labyrinthodon salamandroides*; 2. *L. leptognathus*; 3. *L. pachygnathus*; 4. *L. ventricosus*; and 5. *L. scutulatus*: and I shall here briefly notice the characters exhibited by the bones assignable to the 2nd, 3rd, and 5th species.

Labyrinthodon leptognathus.—The remains which I consider as portions of this species, consist of fragments of the upper and lower jaws, two vertebræ, and a sternum. They were found in the sandstone quarries at Coton End, near Warwick.

The portions of the upper jaw show that the maxillary or facial division of the skull was broad, much depressed, and flattened, resembling the skull of the gigantic Salamander and of the Alligator; and the outer surface of the bones was strongly sculptured, as in the Crocodilian family, but of a relatively larger and coarser pattern. One portion of the upper jaw contains the anterior moiety of the single row of small teeth, or thirty sockets, and the base of one of the great anterior tusks. The bases of the serial teeth project directly from the outer wall of the shallow socket, there being no alveolar ridge external to it. The large anterior fang is three times the size of the first of the serial teeth, and the size of these gradually diminishes as they are placed further back; the length of the common-sized teeth being about two lines, and the greatest breadth one-third of a line. The apical two-thirds of each tooth is smooth, but the basal third is fluted, and anchylosed to the outer wall of the socket. The breadth of the upper jaw, opposite the middle of the dental series, was two inches six lines; in proceeding backwards the jaw gradually expands to three inches, and in proceeding forwards narrows, but in a less degree towards the anterior extremity, and then slightly widens or inclines outwards on account of the large tusks. Where the upper jaw is entire, a portion next the median suture, four lines in breadth, is separated from the maxillary bone by a longitudinal harmonia, and corresponds with the position of the nasal bone in the Crocodile.

On comparing the structure of the cranium of the *Labyrinthodon* with the existing Batrachians, it is true that an important modification will be found to exist. In both the caducibranchiate and perennibranchiate species, the upper maxillary bones do not extend horizontally over the upper surface of the skull, but leave a very wide interval between the maxillary and nasal bones; and the palatal processes of the former contribute as little to form the floor of the nasal cavity: in the Crocodiles, on the contrary, the palatal processes of the maxillary bones extend horizontally inwards, and meet at the middle line of the roof, forming an unbroken floor to the nasal cavity. In the *Labyrinthodon* the superior maxillary bones, as already shown, extend inwards to the nasal bone, constituting with it a continuous roof to the nasal cavities; but the palatal processes, instead of reaching to the middle line, as in the Crocodiles, are very narrow, as in the *Batrachia*. The osseous roof of the mouth is principally composed of a pair of broad and flat bones, analogous to the divided vomer in *Batrachia*, but of much greater relative extent, approaching, in this respect, those of the Menopome, and defending the mouth with a more extensive roof of bone than exists in any Lacertian reptile: physiologically, therefore, the *Labyrinthodon*, in this part of its structure, comes nearest to the Crocodile; but the structure itself, morphologically, is essentially Batrachian. In the Menopome and gigantic Salamander, a row of small teeth extends transversely across the anterior extremity of the vomerine bones: and the occurrence in the *Labyrinthodon* of a similar row, consisting in each palatine bone of three median small teeth and two outer larger ones, marks most strongly its Batrachian nature; and from the outermost tooth a longitudinal row of small and equal-sized teeth is continued backward along the exterior margin of the palatine bone. The whole of this series of palatal teeth is nearly concentric with the maxillary teeth.

In Lacertine reptiles the examples of a row of palatal teeth are rare, and, when present, it is short, and situated towards the back of the palate, upon the pterygoid bones, as in the Iguana and Mosasaur. In Batrachians the most common disposition of the palatal teeth is a transverse row placed at the anterior part of the divided vomer, as in Frogs, the Menopome and gigantic Salamander, and at the posterior part in certain toads. In the Amphiume, on the contrary, the palatal teeth form a nearly longitudinal series along the outer margin of the vomerine bones. The *Labyrinthodon* combines both these dispositions of the palatal teeth, which are arranged transversely across the fore part of the divided vomer and extend backwards along its outer margin. No teeth are placed on the pterygoid bones at the back of the palate as in the Saurians with palatal teeth. The posterior palatine apertures are, however, more completely circumscribed by bone than in most Batrachians, and occupy the same relative position as in the Iguana. The posterior margin only of one of the anterior apertures is exhibited in the specimen here described, but from its curve I infer that the two apertures are not confluent, as in the Crocodile, the Frog, or the Menopome, but that they are distant, as in the Iguana.

From the physiological condition of the nasal cavity it may be concluded that the *Labyrinthodon* differed from the Batrachians and resembled the Saurians in having distinct posterior nasal apertures surrounded by bone, and that its mode of respiration was the same as in the higher air-breathing reptiles. In the shedding and renewal of the maxillary and the transverse palatal teeth, it is evident that the process took place alternately in each row, as in many fishes, whereby the dental series was always kept in an efficient state.

Another instructive fossil is a portion of the left ramus of an under jaw of *Labyrinthodon leptognathus* from the Warwick sandstone. It is six inches long, slender and straight, the symphysial extremity is abruptly bent inwards, and it presents almost as striking a Batrachian character as any of the bones just mentioned. The angular piece is of great breadth, and is continued forward to near the symphysis, forming the whole of the inferior part of the jaw, and extending upon the inner as far as upon the outer side of the ramus, the inner plate performing the function of the detached os operculare in the jaw of Saurians. The dentary bone is supported upon a deep and wide groove along the upper surface of the angular piece, which also projects beyond the groove, so as to form a strong convex ridge on the external side of the jaw, below the dentary piece. This character, which in the large bull-frog (*Rana pipiens*) is confined to the posterior part of the maxillary ramus, is in the *Labyrinthodon* continued to near the anterior extremity. The teeth are long and slender, gradually diminishing in size towards the anterior portion of the jaw, and the fragment presents a linear series of not less than fifty sockets, placed alternately a little more internally; and at the anterior inflected part of the jaw is the base of the socket of a large tooth. The anterior portion of the jaw being broken off, it is uncertain if the serial teeth were continued externally to the anterior tusk, which is a remarkable ichthyoid character noticed in another species of *Labyrinthodon*.

The sockets of the teeth are shallower than in the upper jaw; the outer wall is more developed than the inner, and the anchylosed bases of the teeth more nearly resemble, in their oblique position, those of existing *Batrachia*. With regard to the modification of the microscopic structure of the teeth, I may observe that, between the apex and the part where the inflected vertical folds of the cement commence, the tooth resembles, in the simplicity of its intimate structure, that of the entire tooth of ordinary *Batrachia* and most reptiles; and in the lower or basal half of the tooth the structure described in the works before quoted commences, and gradually increases in complexity.

From the long and slender character of this ramus, the length of the head, as compared with the breadth, approximates more nearly to Crocodilian proportions than to the ordinary Batrachian ones; but among existing Batrachia it resembles most nearly the Amphiume.

A dorsal vertebra from Coton End presents further evidence of the Batrachian nature of the *Labyrinthodon*. It has concave articular cavities at the extremities of the body, a condition now known, among existing reptiles, only in the Geckos, and in the lower or perennibranchiate division of Batrachians. It is a common structure in extinct Saurians, but the depth of the vertebral articular cavities in the *Labyrinthodon* exceeds that in the Amphicœlian Crocodilians and in most Plesiosaurs. The body of the vertebra is elongate and subcompressed, with a smooth but not regularly curved lateral surface, terminating below in a slightly produced, longitudinal, median ridge; and it exhibits the same exceptional condition in the Reptilian class as do the vertebræ of existing Batrachians, in having the superior arch or neurapophysis anchylosed with the centrum. From each side of the base of the neural arch a thick and strong transverse process extends obliquely outwards and upwards.

A symmetrical bone, resembling the episternum of the *Ichthyosaurus*, was associated with the preceding remains. It consists of a stem or middle, which gradually thickens to the upper end, where cross-pieces are given off at right angles to the stem, and support on each a pretty deep and wide groove indicating strongly the presence of clavicles, and thus pointing out another distinction from Crocodiles, in which clavicles are wanting. Most Batrachians possess these bones.

The modifications of the jaws, and more especially those of the bony palate of the *Labyrinthodon leptognathus*, prove the fossil to have been essentially Batrachian, but with affinities to the higher Sauria, leading, in the form of the skull and the sculpturing of the cranial bones, to the Crocodilian group, in the collocation of the larger fangs at the anterior extremities of the jaws to the *Plesiosaurus*, and in one part of the dental structure, in the form of the episternum, and the biconcave vertebræ, to the *Ichthyosaurus*. Another marked peculiarity in this fossil is the anchylosis of the base of the teeth to distinct and shallow sockets, by which it is made to resemble the Sphyræna and certain other fishes. From the absence of any trace of excavation at the inner side of the base of the functional teeth, or of alveoli of reserve for the successional teeth, it may be concluded that the teeth were reproduced, as in the lower Batrachians and in many fishes, especially the higher Chondropterygii, which formed the *Amphibia Nantes* of Linnæus, in the soft mucous membrane which covered the alveolar margin, and that they subsequently became fixed to the bone by anchylosis, as in the Pike and Lophius. This anatomical fact militates strongly against the idea that the *Labyrinthodon* is a Saurian*. No remains of the locomotive organs of the *L. leptognathus* have yet been found.

Labyrinthodon pachygnathus.—The remains of this species, which have been obtained, consist of portions of the lower and upper jaws, an anterior frontal bone, a fractured humerus, an ilium with a great part of the acetabulum, the head of a femur, and two ungual phalanges. A portion, nine and a half inches long, of a right ramus of a lower jaw, in addition to the characters common to it and the fragment of the lower jaw of the *L. leptognathus*, in the structure of the angular and dentary pieces, shows that the outer wall of the alveolar process is not higher than the inner, as in Frogs and Toads, the Salamanders and Menopome, in all of which the base of the teeth is anchylosed to the inner side of an external alveolar plate. The smaller serial teeth are about forty in number, and gradually diminish in size as they approach both ends, but chiefly so towards the anterior part of the jaw. The sockets are close together, and the alternate ones are empty. The great laniary teeth were apparently three in each symphysis, and the length of the largest is considered to have been one and a half inch. A section through the base of the anterior tusk above the socket exhibits the structure described in the Proceedings of the Geological Society, January, 1841, but a section of the second tusk, also taken above the socket, shows a less complex modification of the labyrinthic arrangement, one, viz. which is closely analogous to that at the base of the teeth of the *Ichthyosaurus*. The apical half of the tusks has a smooth and polished surface, and the pulp-cavity is continued, of small size, into the centre of this part of the tooth. In the serial teeth, which in other respects, except size, correspond with the preceding description of the tusks, the central pulp-cavity is more quickly obliterated, but the alveoli are large, moderately deep and complete: the texture of the teeth is dense and brittle. The base of each tooth is anchylosed to the bottom of its socket, as in Scomberoid and Sauroid fishes; but the *Labyrinthodon* possesses a still more ichthyic character in the continuation, preserved in this specimen, of a row of small teeth anterior and external to the two or three larger tusks. A double row of teeth thus occasioned does not exist in the maxillary bones, either superior or inferior, of any Saurian reptile†; but in Batrachia it has been noticed in the lower jaw of the *Cæcilia*, and it is not an uncommon structure in fishes.

A fragment of the superior maxillary bone manifests a striking deviation from the Crocodilian type of structure in the continuation of the palatal plate of the intermaxillary bone for about an inch to the outer side of the base of the external plate or process; while in the Crocodiles the external wall of the intermaxillary bone is united by the whole of its outer margin with the maxillary, and is thence continued along the whole outer contour of the intermaxillary bone. Now in the *Labyrinthodon* the intermaxillary bone presents the same peculiar modification of the Batrachian condition of this bone as in the higher organized Batrachia, the palatal process of the intermaxillary extending beyond the outer plate both externally and, though in a less degree, internally, where it forms part of the boundary of the anterior palatal foramen, whence the outer plate rises in the form of a compressed process from a longitudinal tract in the upper part of the palatal process; it is here broken off near its margin, and the fractured surface gives the breadth of the base of the outer plate, stamping the fossil with a Batrachian character conspicuous above all the Saurian modifications by which the essential nature of the fossil appears at first sight to be masked.

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* It would be highly desirable to determine in how many of the characters above detailed the *Nothosaurus mirabilis*, Muenster, may deviate, like the *Labyrinthodon*, from the Saurian type of structure: it would seem to connect the *Plesiosaurus* with the *Labyrinthodon*.

† The successional teeth in *Plesiosaurus* and *Nothosaurus* are sometimes so far developed before they displace their predecessors as to cause the appearance of a double row.

In the anterior frontal bone there are indications of Crocodilian structure. Its superior surface is slightly convex and pitted with irregular impressions; and from its posterior and outer part it sends downwards a broad and slightly concave process, which appears to be the anterior boundary of the orbit. This process presents near its upper margin a deep pit, from which a groove is continued forwards; and in the corresponding orbital plate of the Crocodile there is a similar but smaller foramen.

From these remains of the cranium of the *Lab. pachygnathus*, it is evident that the facial or maxillary part of the skull was formed in the main after the Crocodilian type, but with well-marked Batrachian modifications in the intermaxillary and inferior maxillary bones. The most important fact which they show is, that this Sauroid Batrachian had subterminal nostrils, leading to a wide and shallow nasal cavity, separated by a broad and almost continuous palatal flooring from the cavity of the mouth; indicating, with their horizontal position, that their posterior apertures were placed far behind the anterior or external nostrils; whereas in the air-breathing Batrachia the nasal meatus is short and vertical, and the internal apertures pierce the anterior part of the palate. It may be inferred, therefore, that the apparatus for breathing by inspiration must have been present in the *Labyrinthodon* as in the Crocodile; and hence still further, that the skeleton of the *Labyrinthodon* will be found to be provided with well-developed costal ribs, and not, as in most of the existing Batrachians, with merely rudimentary styles. Since the essential condition of this defective state of the ribs of Batrachians is well known to be their fish-like mode of generation and necessary distension of the abdomen, it is probable that the generative economy of these fossil reptiles, in which the more complete ribs would prevent the excessive enlargement of the ovaria and oviducts, may have been similar to that of Saurian reptiles.

A fragment of a vertebra of *Lab. pachygnathus* presents analogous characters to the vertebra of the *Lab. leptognathus* previously noticed.

Of the few bones of the extremities which have come under my inspection, one presents all the characteristics of the corresponding part of the humerus of a toad or frog, viz. the convex, somewhat transversely extended articular end, the internal longitudinal depression, and the well-developed deltoid ridge. The length of the fragment is two inches, and the breadth is thirteen lines. The ridges are moderately thick and compact, with a central medullary cavity. In its structure as well as in its general form, the present bone agrees with the Batrachian, and differs from the Crocodilian type.

In the right ilium, about six inches in length, and in the acetabulum, there is a combination of Crocodilian and Batrachian characters. The acetabular cavity is bounded on its upper part by a produced and sharp ridge, as in the frog; and not emarginate at its anterior part, as in the crocodile. Above the acetabulum in the frog the ilium gives off a broad and depressed process, the lower extremity of which is separated from the acetabulum by a smooth concave groove, both of which are wanting in the crocodile, there being only a slight rising of the upper border of the acetabulum. These characters, however, are well developed in the *Labyrinthodon*: but the process, instead of being depressed, is compressed, and its internal extremity is pointed and bent forwards, representing the rudiment of the long anterior process of the ilium in the *Batrachia anoura*; but it does not attain in the *Labyrinthodon* the parallel of the anterior margin of the acetabulum, and the bone terminates in a thick truncated extremity a few lines anterior to the acetabulum; which gives an essential feature of resemblance to the Crocodiles and difference from the

Batrachians. But the most marked difference in this fossil from the crocodile is the length of the ilium posterior to the acetabulum, in which it agrees with the analogous portion of the frog and other tailless Batrachians; while, on the contrary, there is an agreement with the Crocodilian type in the mode of articulation to the vertebral column. In the frog a transverse process of a single vertebra abuts against the anterior extremity of the produced ilium. In the crocodile the transverse processes of two vertebræ are thickened and expanded, and joined to a rough, concave, articular surface occupying the inner side of the ilium, and a little posterior to the acetabular cavity. In the *Labyrinthodon* is a similar well-marked, rough, elongated, concave, articular surface, divided by a non-articular surface, and destined for the reception of the external extremities of two sacral ribs. The *Labyrinthodon* likewise agrees with the crocodile in the lower part of the acetabulum being completed by the upper extremity of the pubis, the anterior and inferior part of the ilium offering an obtuse process at the posterior part of the lower boundary of the acetabular cavity.

As the fragment of the ilium was discovered in the same quarry as the two fragments of the cranium and the portion of the lower jaws, it is probable that they may have belonged to the same animal; and if so, as the portions of the head correspond in size with those of the head of a crocodile six or seven feet in length, but the acetabular cavity with that of a crocodile twenty-five feet in length, then the hinder extremities of the *Labyrinthodon* must have been of disproportionate magnitude compared with those of existing Saurians, but of approximate magnitude with some of the living anourous Batrachians. That such a reptile, of a size equal to that of the species whose remains have just been described, existed at the period of the formation of the New Red Sandstone, is abundantly manifested by the remains of those singular impressions to which the term *Cheirotherium* has been applied. Other impressions, as those of the *Cheirotherium Hercules*, correspond in size with the remains of the *Labyrinthodon Salamandroides*, which have been discovered at Guy's Cliff. The head of a femur from the same quarry in which the ilium was found exactly fits the acetabulum or the articular cavity of that bone. The two toe-bones, or terminal phalanges, resemble those of Batrachians in presenting no trace of a nail, and from their size they may be referred to the hind-feet of the *L. pachygnathus*.

Thus, all these osseous remains from the Warwick and Leamington sandstones agree with each other and with the fossil remains of the great *Mastodonsaurus Salamandroides* of the German keuper in their essentially Batrachian nature. Now it has been suggested by more than one Palæontologist that the impressions of the *Cheirotherium* may have been the foot-prints of a Batrachian; but, in consequence of the peculiarities of the impressions, it is obvious that the animal must have been quite distinct in the form of its feet from any known Batrachian or other reptile. In the attempt to solve the difficult problem of the nature of the animal which has impressed the New Red Sandstone with the Cheirotherian foot-prints, we cannot overlook the fact that we have in the *Labyrinthodon* also a Batrachian reptile, differing as remarkably from all other Batrachians, and from every other reptile in the structure of its teeth: both the footsteps and the fossils are, moreover, peculiar to the New Red Sandstone; and the hypothesis that the footsteps of the *Cheirotherium* are those of the *Labyrinthodon*, which I have proposed in my Memoir read before the Geological Society, may be allowed to be supported by more facts than had before been brought to bear upon the question.

Labyrinthodon scutulatus.—The remains, to which this specific designation has been applied, composed a closely and irregularly aggregated group of bones imbedded in sandstone, and manifestly belonging to the same skeleton;

they consist of four vertebræ, portions of ribs, a humerus, a femur, two tibiæ, one end of a large flat bone, and several small osseous, dermal scutes. The mass was discovered in the new red sandstone at Leamington, and was transmitted to me by Dr. Lloyd in the summer of 1840.

The vertebræ present biconcave articular surfaces similar to those of the other species. In two of them, the surfaces slope in a parallel direction obliquely from the axis of the vertebræ, as in the dorsal vertebræ of the frog, indicating an habitual inflexion of the spine, analogous to that in the humped back of the frog. The neurapophyses are anchylosed to the vertebral body. The spinous process rises from the whole length of the middle line of the neurapophysial arch, and its chief peculiarity is the expansion of its elongated summit into a horizontally flattened plate, sculptured irregularly on the upper surface. A similar flattening of the summit of the elongated spine is exhibited in the large atlas of the toad. The body of the vertebræ agrees with that of the *L. leptognathus*. The humerus is an inch long, regularly convex at the proximal extremity, and expanded at both extremities, but contracted in the middle. A portion of a somewhat shorter and flatter bone is bent at a subacute angle with the distal extremity, and resembles most nearly the anchylosed radius and ulna of the Batrachia.

The femur wants both the extremities; its shaft is subtrihedral and slightly bent, and its walls are thin and compact, including a large medullary cavity. The tibiæ are as long, but thicker and stronger than the femur. They had lost their articular extremities, but exhibited that remarkable compression of their distal portion which characterizes the corresponding bone in the Batrachia: they likewise have the longitudinal impression along the middle of the flattened surface. The length of the more perfect shaft is 2 inches 1 line.

With respect to the osseous dermal scuta, though they form a striking instance of the Crocodilian affinities of the Leamington fossil, yet as these detached superficial bones are the most liable to be separated from the fragmentary skeleton of the individual they once clothed, the negative fact of their not having been found associated with the remains of the *Labyrinthodon* in other localities, proves nothing in regard to a difference of dermal structure between the Leamington and Warwick species. Indeed no anatomist can contemplate the extensive development and bold sculpturing of the dermal surface of cranial bones in the *Labyrinthodon pachygnathus* and *L. leptognathus* without a suspicion, that the same character may have been manifested in bony plates of the skin in other parts of the body. Admitting for a moment this structure to be proved, to what extent, it will be asked, does it affect the claims of the *Labyrinthodon* to be admitted into the order of Batrachians, in which every known species is covered with a soft, lubricous and naked integument, without scales or scuta? In reply, I have observed*, that the skin is the seat of variable characters in all animals; and, if considered apart from the modifications of the osseous and dental systems, is apt to mislead the naturalist who is in quest of the real affinities of a species: thus we have in the Trionyx an example of a soft-skinned animal among Chelonian reptiles.

The following are the names of the species of extinct Reptiles in the order in which they are described in the second and concluding part of the Report:—

Order ENALIOSAURIA.

Pliosaurus brachydeirus, Owen.
Pliosaurus trochanterius, Owen.

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* Geological Proceedings, January 1841.

Order CROCODILIA.

Crocodilus Spenceri, Buckland.
Suchosaurus cultridens, Owen.
Goniopholis crassidens, Owen.
Teleosaurus Chapmanni, König.
Teleosaurus Cadomensis, Geoffroy.
Teleosaurus asthenodeirus, Owen.
Steneosaurus brevirostris (rostro-minor), Geoffroy.
Poikilopleuron Bucklandi, Deslongchamps.
Streptospondylus Cuvieri, Owen.
Streptospondylus major, O.
Cetiosaurus brevis, O.
Cetiosaurus brachyurus, O.
Cetiosaurus medius, O.
Cetiosaurus longus, O.

Order DINOSAURIA.

Megalosaurus Bucklandi, Cuvier.
Hylæosaurus armatus, Mantell.
Iguanodon Mantelli, Cuvier.

Order LACERTILIA.

Mosasaurus Hoffmanni, Conybeare.
Leiodon anceps, Owen.
Raphiosaurus subulidens, Owen.
Lacerta, sp. ind., Eocene.
Lacerta, sp. ind. (allied to *Scincus*), Oolite.
Rhynchosaurus articeps, Owen.
Thecodontosaurus antiquus, Riley and Stutchbury.
Palæosaurus cylindrodon, Riley and Stutchbury.
Palæosaurus platyodon, Riley and Stutchbury.
Cladyodon Lloydii, Owen.

Order PTEROSAURIA.

Pterodactylus macronyx, Buckland.
Pterodactylus, sp. ind.

SAURIA INCERTÆ SEDIS.

Polyptychodon, Owen.
Rysosteus, Owen.

Order CHELONIA.

Testudo Duncani, Owen.
Testudo, sp. ind. Oolite.
Emys testudiniformis, O.
Platemys Bowerbankii, O.
Platemys Bullockii, O.
Platemys Mantelli, Cuvier.
Tretosternon punctatum, O.
Emys, sp. ind. Kimmeridge Clay.
Emys, sp. ind. New Red Sandstone.
Trionyx, sp. ind.
Chelone planiceps, O.
Chelone obovata, O.

Chelone, sp. ind. Wealden.
Chelone pulchriceps, O.
Chelone Benstedi, Owen.
Chelone longiceps, O.
Chelone breviceps, O.
Chelone convexa, O.
Chelone subcristata, O.
Chelone latiscutata, O.

Order OPHIDIA.

Palæophis toliapicus.

Order BATRACHIA.

Labyrinthodon Salamandroides, Owen.
Labyrinthodon leptognathus, O.
Labyrinthodon pachygnathus, O.
Labyrinthodon ventricosus, O.
Labyrinthodon scutulatus, O.

SUMMARY.

A retrospective glance at the catalogue of Reptiles which formerly existed on that portion of the earth's surface constituting the present small island of Britain, and which are now extinct, must call forth such novel and surprising reflections on the dealings of Providence with the animated beings of this planet, as may well lead, in the first place, to a questioning of the truth of the affirmations with which the present summary commences. Did the numerous, strange, and gigantic representatives of the several orders of Reptiles actually at any time live and move and propagate their kind in the localities where their bones are now so abundantly found? Are not these bones the relics rather of antediluvian creatures, which perished in the great historical Catastrophe of Water, and have been washed from latitudes suitable to their existence to more northern shores? Are the British Fossil Reptiles actually extinct, and may not some living representatives of the Labyrinthodons, Enaliosaurs, Dinosaurs, &c., still remain to be discovered in those warmer regions where alone large species of reptiles are now known to exist?

Such questions and explanations of the phænomena which are the subject of the present Report will be most likely to suggest themselves to those who are not conversant with the truths of Geology, and who may never have been eyewitnesses of the circumstances under which fossil bones of reptiles are found.

In many cases these circumstances are so opposed to any that can be conceived to have been produced by the operation of a superincumbent bed of waters upon the present surface of the earth during a period of less than one year, that the earliest observers to whom the operations of a temporary general deluge suggested the first explanation of the appearance of the remains of a large and strange animal, were irresistibly led to the conviction that the conditions under which such fossil animal was found were wholly inexplicable on the supposition of its carcase having been left by the retiring waters of a flood. Thus the good Quaker of Whitby, in his letter to Dr. Fothergill, recounting the discovery of the extinct species of Crocodile that now bears his name (*Teleosaurus Chapmanni*), says, "The bones were covered five or six feet with the water every full sea, and were about nine or ten yards from the cliff, which is nearly perpendicular, and about sixty yards high, and is continually wearing away by the sea washing against it: and, if I may judge by what has happened in my own memory, it must have extended beyond these bones less than a century ago. There are several regular strata or layers of stone, of some yards thickness, that run along the cliff nearly parallel to the horizon and to one another. I mention this to obviate an objection, that this animal may have been upon the surface, and in a series of years may have sunk down to where it lay, which will now appear impossible, at least when the stones, &c. have had their present consistence*."

It must be obvious, indeed, that the regular succession of horizontal layers, —"beginning from the top, of earth, clay, marble, stones, both hard and soft, of various thicknesses, till it comes down to the black slate or alum rock†,"— mounting to the height of near two hundred feet above the petrified skeleton, could not have been the result of the deposit of a temporary overflow of diluvial waters continuing for a few months, supposing even those waters to have been thickly charged with the ruined surface of the old earth. Succession of strata, as of all other phænomena, must take place in successive periods of time; the hundredth layer of lias, counting downwards, which contained the skeleton of the strange Crocodile, must once have been the uppermost, and some time must have elapsed between the deposition of that stratum with its organized contents and the deposition of the succeeding layer above.

If the fossilized bones of the animals described in the present memoir had been drifted to this island by a flood, they would be found mingled together in the superficial strata usually termed 'diluvial,' and would characterize no particular formation or locality. But the reverse of this is the fact; and it is the cumulative evidence of the limitation of certain genera to particular formations that gives its chief value to the present class of researches.

In the most superficial fossiliferous deposits which indicate the last operation of a body of water, either frozen or fluid, upon the surface of the British islands, no remains of reptiles have come under my observation. Cuvier alludes to a single bone of a crocodile said to have been found associated with the usual fossils of the drift or diluvium at Brentford‡: but no other evidence of any other species or genus of Reptile, which is now confined to warmer regions of the globe, has yet been recognized in the British strata called diluvial, or in any that are more recent than the oldest Tertiary formations.

In these Eocene beds, accumulated in some localities to the thickness of three hundred feet and upwards, the remains of crocodiles, tortoises, trionyxes, turtles, and large serpents, are more or less common. These fossils severally exhibit well-marked and unequivocal specific differences when compared with the bones of their known existing congeners; but their osteology does not present any modifications of generic value. The nearest approach to this degree of deviation occurs in the Eocene Chelonian Reptiles, as in that species of turtle from Sheppey, which combines the jaws of a Trionyx with the bony helmet of a Turtle, and presents an extent of ossification of the buckler nearly equalling that of an Emys. The Eocene Crocodile exhibits all the characters of the osseous and dental systems which distinguish the genus as restricted in the latest systems of Erpetology; and whilst it cannot be identified with any known species, most resembles, not the commonest and nearest existing Crocodile, as that of the Nile, but a rarer and more remote one, viz. the *Crocodilus Schlegelii* of Borneo. Not any species of Reptile of the Tertiary strata has been discovered in the chalk upon which those strata immediately rest.

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* Philosophical Transactions, 1758, p. 688.

† Ibid., p. 789.

‡ Dr. Buckland has suggested to me that this bone was probably washed out of the clay beneath the diluvium.

A small lizard, closely corresponding in vertebral structure with existing species, but differing in its dentition; and a gigantic marine species (*Mosasaurus*), which is the first, in the present descending survey, to offer osteological and dental combinations wholly unknown in existing Saurians,—constitute the representatives of the Lacertian order in the cretaceous beds, which form the most recent of the secondary deposits.

In tracing upwards the extinct Reptiles we find that the union of the vertebræ by a hinder ball received into an anterior cup, a structure which, with an insignificant exception—the Gecko—prevails throughout the Saurian order as it now exists, commences with the Lacertian Reptiles which perished during the deposition of the chalk, and, in the Crocodilian and Ophidian Reptiles, is first found in the species which made their appearance during the deposition of the London clay.

Of the Crocodilian order I have yet seen no unequivocal representatives from the British chalk.

All the well-determined Chelonians of the cretaceous period are marine species, and are equally distinct, with the Lacertians, from those of the superimposed tertiary beds.

The most interesting fact which the Palæontology of the cretaceous period has yielded, with reference to the great Saurian division of the class of Reptiles, is the commencement, or rather the last appearance of the fossil remains of an order of Reptiles (*Enaliosauria*) now altogether extinct. I have determined portions of the lower jaw with teeth of a large species of *Ichthyosaurus* from the lower chalk between Folkstone and Dover, which is very closely allied to, if not identical with, the *Ichthyosaurus communis*. The femur of a large *Plesiosaurus* has been obtained from the chalk of Shakspeare's Cliff. Remains of more than one species of *Plesiosaurus* occur in the Gault, and are associated with the *Ichthyosaurus* in the greensand near Cambridge, and in the Kentish Rag near Maidstone.

In the greensand also we first meet with evidences of Reptiles exhibiting modifications of structure, especially of the locomotive extremities, as remarkable and as different from those of existing species as are presented by the *Enaliosauria*, but pointing as strongly to an adaptation for terrestrial life as does the Enaliosaurian structure to aquatic existence. The specimen of the unquestionably terrestrial Saurian here alluded to, viz. the *Iguanodon*, is the more remarkable in the subcretaceous marine strata, in consequence of its presenting the largest proportion of the connected skeleton of the same individual of this species that has hitherto been found.

Gigantic Crocodilian Reptiles, removed by generic modifications of structure from the Eocene and existing Crocodiles, now likewise begin to be indicated, as by the teeth of the *Polyptychodon* from the greensand quarry at Maidstone, and by the large bones of the extremities from the quarries of a corresponding stratum at Hythe.

The Chelonian from the greensand (*Chelone pulchriceps*) differs from the Eocene and all existing turtles in a very interesting modification of the anatomy of the cranium.

In the Wealden group of freshwater strata, the Enaliosaurian order continues to be represented by the *Plesiosaurus*, but no remains of the more strictly marine genus, *Ichthyosaurus*, have yet been discovered. This circumstance corresponds with the more strict adaptation for marine existence which the structure of the *Ichthyosaurus* presents, and corroborates the inference that the *Plesiosaurus* lived nearer the shore, and ascended estuaries. The re-appearance of the *Ichthyosaurus* in the chalk formations proves that it had continued to exist in the neighbouring ocean, and indicates, perhaps, that the deposition of the cretaceous beds was related to the formation of the Wealden group by proximity of time as well as place. The terrestrial group of gigantic Reptiles receives in the Wealden an accession of two new genera, viz. *Hylæosaurus* and *Megalosaurus*; and the remains of both these, and especially of the *Iguanodon*, are so abundant, that the Wealden strata may be regarded as the metropolis of the Dinosaurian order *.

The amphibious Crocodiles might be expected, from their known habits at the present day, to have left abundant evidences of their remains in strata, which seem to have been deposited at the estuary or mouth of some great river; in a climate, indicated by its vegetable fossils to have been warmer or more equable than at present; and during a period of time which permitted the accumulation of 1000 feet of strata. Accordingly, the Crocodilian order of Reptiles has been found to be represented by several distinct genera in the Wealden formations.

Some new characters and modifications of structure might also have been anticipated in those Crocodilians which existed at a period antecedent to the deposition of about 1500 feet of cretaceous strata, which, again, preceded the formation of the whole series of superimposed tertiary and diluvial beds. Nevertheless, the remarkable modifications which all the Wealden Crocodilians present in the structure of their vertebræ, as compared with the Eocene and existing Crocodiles, could not have been anticipated; and even now that they are ascertained by repeated observation, some of them still remain inexplicable in relation to any conjectural habits of the species, or hypothetical conditions under which they actually existed. We may understand why the ball-and-socket articulation of the vertebræ of the present amphibious Crocodiles frequenting dry land, should be exchanged for a joint having elastic substance included between two concave articular surfaces, as a structure better adapted to Crocodiles more habitually living and moving in water; but these Crocodiles with biconcave vertebræ are associated with others having plano-concave vertebræ, and also with a species having vertebræ joined by ball-and-socket articulations. And the difficulty is not diminished by the remarkable fact of the latter structure being the reverse of that in recent Crocodiles, the ball and the cup having changed places in the extinct *Streptospondylus*; and having assumed the position which they present in certain Sauroid fishes, and in the dorsal and cervical vertebræ of some of the herbivorous Mammalia.

The biconcave, plano-concave, and convexo-concave modifications of the vertebræ are not the only points in which the extinct Crocodilians of the Wealden strata differ from those of the London clay and from the existing species. The genus *Goniopholis*, for example, exhibits a remarkable development of its dermal armour, the large quadrangular scutes of which, interlocked by teeth received into depressions, are gigantic representations of the scales of some of the Ganoid fishes; while the smaller hexagonal and pentagonal scutes † were articulated together by marginal sutures, as in the dermal bony covering of the armadillo. The *Poikilopleuron* exhibits a medullary cavity in the body of the vertebræ, and a double origin of the spinous process. The *Suchosaurus* offers a very striking change in the form of the teeth. The *Cetiosaurus* surpasses all modern Crocodiles in its enormous bulk, which almost rivals that of the Whales, its successors in the modern seas. The genus *Streptospondylus*, which, in repeating the ball-and-socket structure, offers the strange anomaly of an anterior position of the ball and a posterior one of the socket, makes its first appearance in the Wealden by a species which must have been little inferior to the *Cetiosaurus* in length.

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* Dr. Mantell calculates that not less than seventy individuals of the *Iguanodon*, varying in age and magnitude, from the young just escaped from the shell to the mature animal, with a femur of more than a yard in length, have come under his examination; and he justly observes that "more than thrice that number have, in all probability, been destroyed by the workmen, and altogether eluded the observation of the Palæontologist."—See his Memoir in the Philosophical Transactions, 1841.

† These have been discovered since the first sheets of this Report went to press by my friend Mr. Holmes of Horsham, in the Wealden strata near that town.

The huge terrestrial Saurians of the Wealden deviate in so much greater a degree than the Crocodilians from the existing types, as to render the formation of a distinct order for their reception necessary.

It does not appear that any of the Chelonians of the Wealden period are specifically identical with those of the chalk. A new and singular osculant genus, *Tretosternon*, here represents the *Trionyces* of the Eocene freshwater or estuary formations. A new species of Turtle, with an Emydian form of shell, occurs in the Purbeck limestone; and the head of a turtle from the Portland stone, upon which the Purbeck beds immediately rest, exhibits the same distinction of the separate nasal bones, as does the skull of the turtle from the greensand, but combined with well-marked specific differences in other parts.

The Portland stone introduces us to the great Oolitic series, in which we lose sight of the *Iguanodon*, *Hylæosaurus*, *Goniopholis*, and *Suchosaurus*, but find that the *Megalosaurus*, *Poikilopleuron*, *Cetiosaurus*, *Streptospondylus*, and *Plesiosaurus*, are genera common to the Wealden and Oolitic periods.

Now also the genus *Ichthyosaurus*, which was represented by a single species in the chalk epoch, astonishes us by the number of individuals, and the great variety of specific modifications and varieties of form and bulk, under which it existed in the oolitic periods; especially in the older divisions of the oolite, as the lias. The number and variety of Plesiosaurian Reptiles are even more surprising, and the modifications of their skeleton being more marked and various, proportionally facilitate the determination of the species. The largest of these Plesiosaurian Reptiles deviates, indeed, so far from the typical structure of the genus as to merit subgeneric distinction. This subgenus, the *Pliosaurus*, characterizes the Kimmeridge and Oxford clays, but appears not to have existed at the period of the lower oolite.

In the place of the *Goniopholis* and *Suchosaurus*, the Crocodilian genera, *Steneosaurus* and *Teleosaurus*, with the subgenera, *Aelodon*, *Mystriosaurus*, *Macrospondylus*, &c. (separated, perhaps, without sufficient reason, from the first two typical genera of Amphicœlian Crocodiles), make their appearance in the oolitic strata, especially in the lower divisions. The long and narrow snouts, sharp and slender teeth, short fore-limbs, and imbricated scutation of these extinct Crocodilians, attest, with their vertebral structure, their adaptation to an aquatic life, and to the capture of a prey not more highly organized than fishes.

Some small species of Crocodilians and Lacertians have left a few bones of their extremities in the oolitic slate of Stonesfield; and a most singular order of Reptiles now makes its appearance, the skeleton of which exhibits a modification of the Lacertian type of structure closely analogous to that by virtue of which the mammalian Bat is endowed with the powers of flight. The flying Dragons, called *Pterodactyli*, were of small size, and are restricted, like the *Teleosauri* and *Steneosauri*, to the oolitic group. All the other genera are continued into the Wealden,—the *Poikilopleuron* and *Megalosaurus*, by identical species,—the other genera by species which are distinct from those of the oolite. The *Plesiosaurus* and *Ichthyosaurus* existed, as we have seen, as late as the deposition of the chalk. The analogy between the extinct Reptiles and Fishes, in regard to the great proportion of genera which are common to the Wealden and Oolite, and the small proportion which is continued into the Cretaceous formations, offers a valuable corroboration of the subordinate character of the Wealden group as a member of the great Oolitic series.

No species or genus of Saurian represented by fossils from the Oolite has yet been discovered in older or lower strata in the British Islands. The *Rysosteus* is apparently confined to the bone-bed under the lias, which may be regarded as the oldest member of the Oolitic series in these islands.

The Reptiles of the Poikilitic strata exhibit deviations from the typical structure of the recent families, together with osculant characters joining groups now distinct, as great and even more anomalous than occur in any of the preceding extinct genera.

The *Rhynchosaurus* of the New Red Sandstone near Shrewsbury manifests Ornithic and Chelonian modifications, grafted upon an essentially Lacertian type of cranial structure; no approach even to the form of its extraordinary head being made by any other of the extinct members of the Saurian order. The vertebræ of the *Rhynchosaurus* differ from those of existing Lizards, Chelonians, and Birds, and combine the biconcave structure with the oblique processes and costal articulations of the vertebræ of recent Lizards.

The Labyrinthodonts of the same formation exhibit a different but an equally remarkable combination of characters, Crocodilian modifications being superinduced upon a fundamental organization of the Batrachian type. The structure of the teeth in this remarkable family, which is the most complex that has hitherto been met with in the whole animal kingdom, is unique in the class of Reptiles, and is but partially and comparatively feebly repeated in that of Fishes. It is highly probable that the modifications of the locomotive extremities were as peculiar as the dental characters, if we may judge from the foot-prints of the so-called *Cheirotherium*, to which the Labyrinthodonts alone have at present an equitable claim.

Finally, the *Palæosaurus* and other genera of the Magnesian conglomerate, like the so-called Monitors of Thuringia, are lizards which combined a thecodont type of dentition, with biconcave vertebræ, having the superadded peculiarity of a series of ventricose excavations in the bodies of the vertebræ for the spinal chord, instead of a cylindrical canal.

Below the New Red Sandstone system, notwithstanding that the older deposits, as the coal-measures, have been more thoroughly explored by man than any other geological formation, no trace of a vertebrate animal more highly organized than a fish, has been detected.

From this survey it is evident that many races of extinct reptiles have succeeded each other as inhabitants of the portion of the earth now forming Great Britain; their abundant remains, through strata of immense thickness, show that they existed in great numbers, and probably for many successive generations. Their coprolites prove that they fed upon organized beings coexisting with them and characterizing the same strata, but now equally extinct with their devourers.

To what natural or secondary cause, it may then be asked, can the successive genera and species of Reptiles be attributed? Does the hypothesis of the transmutation of species, by a march of development occasioning a progressive ascent in the organic scale, afford any explanation of these surprising phænomena? Do the speculations of Maillet, Lamarck and Geoffroy derive any support or meet with additional disproof from the facts already determined in the reptilian department of Palæontology?

A slight survey of organic remains may, indeed, appear to support their views of the origin of animated species; but of no stream of science is it more necessary, than of Palæontology, to 'drink deep or taste not*.'

Of all vertebrated animals, the Reptiles form the class which is least fixed in its characters, and is most transitional in its range of modifications; the lowest organized species are hardly distinguishable from fishes, and the highest manifest so great an advance in all the important systems of their organism, that naturalists are not yet agreed as to whether reptiles ought to remain in one class or form two. Reptiles are, besides, the only class of vertebrate animals in which certain species undergo, after birth, a metamorphosis as singular and extreme as in insects.

If the progressive development of animal organization ever extended beyond the acquisition of the mature characters of the individual, so as to abrogate fixity of species by a transmutation of a lower into a higher organization, some evidence of it ought surely to be obtained from an extensive and deep survey of that class of animals which, whilst intermediate in organization between fishes and mammals, prevailed most on the earth during the long periods that intervened between the time when the only vertebrate animals were fishes, and the tertiary and modern epochs when mammals have become abundant, and have almost superseded reptiles in the herbivorous and carnivorous departments of the economy of nature.

In accordance with this not unreasonable expectation, the reptiles of the Magnesian conglomerate and New Red Sandstone ought to have been organized according to the type of the most fish-like perennibranchiate Batrachians; and the Fishes of the older strata, if they tended to a higher stage of development, ought, upon achieving the passage to the Reptilian class, to have entered it at its lowest step.

It is true, indeed, that the most characteristic Reptilian remains of the New Red Sandstone do belong essentially, as by their double occipital condyle, their vomerine palatal bones and teeth, &c., to the Batrachian order; but had the Labyrinthodonts now existed, instead of ranking as the lowest members of that order, they would most unquestionably have been esteemed the highest. And, as in the existing diversified order of Batrachia, one family† represents Fishes, a second‡ Serpents, a third genus§ Chelonians, and a fourth|| Lizards; so would the now lost Labyrinthodonts have formed Batrachian representatives of the highest order of Reptiles, viz. the Crocodilians. Here, therefore, we find the Batrachian making its first appearance under its highest, instead of its lowest or simplest conditions of structure. To use the figurative language of the transmutation theory, the Labyrinthodonts are degraded Crocodiles, not elevated Fishes.

But the hypothetical derivation of reptiles from metamorphosed fishes is more directly negatived by the fact, that the Batrachian type is not that under which reptiles make their first appearance in the strata which succeed the coal-measures. The Monitors of the Thuringian Zechstein are older than the Labyrinthodonts of the Keuper; and among British Reptiles, the thecodont Lizards of the Magnesian conglomerate have equal claims to a more ancient origin.

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* The following are the latest terms in which the transmutation-theory has been promulgated, as supported by Palæontology:—"The life of animals exhibits a continued series of changes, which occupy so short a period that we can generally trace their entire order of succession, and perceive the whole chain of their metamorphoses. But the metamorphoses of species proceed so slowly with regard to us, that we can neither perceive their origin, their maturity, nor their decay; and we ascribe to them a kind of perpetuity on the earth. A slight inspection of the organic relics deposited in the crust of the globe, shows that the forms of species, and the whole zoology of our planet, have been constantly changing, and that the organic kingdoms, like the surface they inhabit, have been gradually developed from a simpler state to their present condition."—Dr. Grant's Lectures on Comparative Anatomy, Lancet, 1835, p. 1001.

† Perennibranchiata. ‡ Ceciliadæ. § Pipa. || Salamandra.

The questions, which the unbiased collector of evidence bearing upon the fixity or mutability of species has next to resolve respecting these primæval Lizards, are, whether they appeared under the form of the low-organized species which one naturalist classes with *Sauria*, another with *Ophidia*, or whether they exhibit indications of having emerged, by progressive development of structure, from any lower organized pre-existing group of cold-blooded animals? To these inquiries the Palæontologist must reply, that the thecodont Lizards of the Zechstein and Magnesian conglomerates combine well-organized extremities, with teeth implanted in distinct sockets, instead of being soldered, as in frogs, to a simple alveolar parapet; and that therefore if they existed at the present day, they would take rank at the head of the Lacertian order, and not among the families most nearly allied to the inferior reptiles. Neither are the modifications of the skeleton of the Rhynchosaur from the New Red Sandstone such as indicated that singular Lacertian to have been derived from the Ophidian or Batrachian orders; but, on the contrary, they connect it more closely than any known recent species, with Chelonia and Birds.

The nearest approximation to the organization of fishes is made by the *Ichthyosaurus*, an extinct genus which appears to have been introduced into the ancient seas subsequent to the deposition of the strata inclosing the remains of the thecodont Lizards. The ichthyic characters of this genus of marine Saurians are not of a very important kind, being limited, like the modifications of the mammalian type in Whales, to a relationship with locomotion in water, while all the modifications of the skeleton which are connected with the respiratory, digestive or generative functions, are conformable with the highest or Saurian type of reptiles; such as the cranial anatomy, the large size of the intermaxillary bones excepted,—the dental structure, which corresponds with that of the posterior teeth in Alligators,—the articulation of the neurapophyses to the bodies of the vertebræ,—the complicated pectoral arch,—the sternum and complete abdominal cincture of ribs*, &c. The circle of numerous imbricated sclerotic bones reaches its maximum of development in the *Ichthyosaurus*; but this is an exaggeration of a structure feebly shadowed forth in some existing Saurians, and more strongly shown in Birds, rather than a repetition of the simple bony sclerotic cup in Fishes. By no known forms of fossil animals can we diminish the wide interval which divides the most sauroid of Fishes from an *Ichthyosaurus*.

This most extraordinary Reptile is a singular compound in which Ichthyic, Cetacean, and Ornithic characters are engrafted upon an essentially Saurian type of structure. The *Ichthyosaurus* is, therefore, just such a form of animal as might be expected, were specific forms unstable, to demonstrate a mutation of characters or some tendency towards a progressive development into a higher and more consistent type of organization. Nor is the field for testing the transmutation theory less ample than the subject is favourable. We have the opportunity of tracing the *Ichthyosauri*, generation after generation, through the whole of the immense series of strata which intervene between the new red sandstone and the tertiary deposits. Not only, however, is the generic type strictly adhered to, but the very species, which made its first abrupt appearance in the lowest of the oolitic series, maintains its characters unchanged and recognizable in the highest of the secondary strata. In the chalk formations, for example, the genus *Ichthyosaurus* quits the stage of existence as suddenly as it entered it in the lias, and with every appreciable osteological character unchanged.

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* This structure proves that the mode of generation of the *Ichthyosaurus* must have resembled that of the Crocodile, and not that of the Batrachians or Fishes.

Of the different species of the *Ichthyosaurus*, founded upon minor modifications of the skeleton, several appear contemporaneously in the strata where the genus is first introduced; and those which remain the longest manifest as little change of specific as of generic characters. There is no evidence whatever that one species has succeeded or been the result of the transmutation of a former species. The tenuirostral *Ichthyosaurus* existed at the same time, and under the same external influences, as the stronger and shorter jawed *Ichthyosaurus communis*; just as the tenuirostral *Delphinus Gangeticus* coexists at present with the short-jawed porpoise.

If the relative periods of existence of the different Enaliosaurian reptiles were not well ascertained, and room were allowed for conjecture as to their successive appearance on this planet, it would be as easy as seductive to speculate on the metamorphoses by which their organic framework, influenced by varying conditions, during a lapse of ages, might have been gradually modified, so as to have successively developed itself from an Ichthyosaur to a Plesiosaur, and thence to a Crocodile.

We may readily conceive, for example, the fish-like characters of the vertebral column of the *Ichthyosaurus* to have been obliterated by a filling-up of the intervertebral cavities through ossification of the intermediate elastic tissue, and the Plesiosaurian type of vertebra to be thus acquired. The normal digits of the fin might be supposed to become strengthened and elongated by more frequent reptation on dry land, and thus to cause an atrophy of the supernumerary fingers: phalanges of a more saurian figure might have been produced by the confluence of a certain number of digital ossicles: the head might be shortened by a stunted growth of the intermaxillary bones, and thus be reduced to Plesiosaurian proportions. The teeth might become more firmly fixed by the shooting of bony walls across their interspaces, as in the young Crocodiles. If we now elongate the bodies of the vertebræ, reduce some twenty pairs of anterior ribs to hatchet-bones, place the fore-paddles at a corresponding distance from the head, and the hind-paddles proportionally nearer the end of the tail, little more will be required to complete the transmutation of the Ichthyosaur into the Plesiosaur.

If next, in adaptation to a gradual change of surrounding circumstances, the jaws of the Plesiosaur became lengthened to the proportions of those of the tenuirostral Ichthyosaur, but at the expense of the maxillary, instead of the intermaxillary bones, preserving the socketed implantation of the teeth; if, to balance the elongation of the jaws the neck at the same time shrank to nearly its former Ichthyosaurian proportions, with some slight modifications of the Plesiosaurian type of the vertebræ; if a further development and a more complete separation of the digits of the fore and hind members were to take place, so that they might serve for creeping as well as swimming; if the exposure of the surface to two different media, and of the entire animal to perils of land as well as of sea, were to be followed by the ossification of certain parts of the skin, and the acquisition, by this change, of a dermal armour,—such we might conceive to be the leading steps in the transmutation of the Plesiosaur into the Teleosaur.

And if the three forms of extinct Saurians, whose changes of specific and generic characters have thus been speculated on, had actually succeeded each other in strata successively superimposed in the order in which they have here been hypothetically derived from one another, some colour of probability might attach itself to this hypothesis, and there would be ground for searching more closely into the anatomical and physiological possibilities of such transmutations. *Ichthyosaurus*, *Plesiosaurus* and *Teleosaurus* are, however, genera which appeared contemporaneously on the stage of vital existence: one neither preceded nor came after the other. How the transmutation theory is to be reconciled to these facts is not obvious; nor to these other, viz. that the Teleosaur ceases with the oolite, while the Ichthyosaur and Plesiosaur continue to co-exist to the deposition of the chalk, and disappear together alike unchanged; the Ichthyosaur manifesting as little tendency to develop itself into a Plesiosaur, as this to degrade itself into the more fish-like modification of the Enaliosaurian type.

If it were urged that the *Streptospondylus*, or Crocodile with ball-and-socket vertebræ, of which the remains occur in later secondary strata, when the Teleosaur had ceased to exist, might be a modification of the apparently extinct amphicœlian Crocodile, in which the vertebræ had undergone a progressive development, analogous to that by which the biconcave joints of the vertebræ of the Tadpole are actually converted into the ball-and-socket joints of those of the mature Frog, the facts of both geology and anatomy again oppose themselves to such an hypothesis: for the remains of the *Streptospondylus* occur likewise in the Whitby lias, which is the earliest formation characterized by remains of the *Teleosaurus*; and the modifications of the vertebral structure, by which the *Streptospondylus* differs from its ancient contemporary, and which it retains unaltered throughout the whole series of oolitic strata, is no approximation to the ball-and-socket structure of modern Crocodiles which first appears in the *Mosasaurus* and the Eocene Crocodiles, but is the very reverse. As reasonably might we infer that the Teleosaur was an intermediate form between the *Streptospondylus* and modern Crocodiles, and that the anterior ball had first subsided, and a sub-biconcave type of vertebræ had been produced before the posterior ball, which characterizes the vertebræ of recent Crocodiles, was finally developed.

If the present species of animals had resulted from progressive development and transmutation of former species, each class ought now to present its typical characters under their highest recognized conditions of organization: but the review of the characters of fossil Reptiles, taken in the present Report, proves that this is not the case.

No reptile now exists which combines a complicated and thecodont dentition with limbs so proportionally large and strong, having such well-developed marrow bones, and sustaining the weight of the trunk by synchondrosis or anchylosis to so long and complicated a sacrum, as in the order *Dinosauria*.

The Megalosaurs and Iguanodons, rejoicing in these undeniably most perfect modifications of the Reptilian type, attained the greatest bulk, and must have played the most conspicuous parts, in their respective characters as devourers of animals and feeders upon vegetables, that this earth has ever witnessed in oviparous and cold-blooded creatures. They were as superior in organization and in bulk to the Crocodiles that preceded them as to those which came after them.

There is not the slightest ground for affirming that the procœlian Gavial of the present day is in any respect more highly organized than the opisthocœlian Gavial of the oldest lias. If the differences of vertebral structure in these Crocodilians were contrasted, in reference to their relative approximation to the vertebral structure of the higher animals, the resemblance of the ball-and-socket joints of the spine of the *Streptospondylus* to those of certain mammals would give precedence in organic perfection to the primæval Gavial.

If, therefore, the extinct species, in which the Reptilian organization culminated, were on the march of development to a higher type, the *Megalo-*

saurus ought to have given origin to the carnivorous mammalia, and the herbivorous should have been derived from the *Iguanodon*. But where is the trace of such mammalia in the strata immediately succeeding those in which we lose sight of the relics of the great Dinosaurian Reptiles? Or where, indeed, can any mammiferous animal be pointed out whose organization can by any ingenuity or licence of conjecture, be derived without violation of all known anatomical and physiological principles, from transmutation or progressive development of the highest reptiles?

If something more than a slight inspection be bestowed upon the organic relics deposited in the crust of the globe, we learn that the introduction of mammalia on that crust is independent of the appearance of the highest forms of Reptiles. The small insectivorous mammals of the lower oolite* are contemporary with the most ancient Dinosaur, and are anterior to the *Iguanodon*.

The period when the class of Reptiles flourished under the widest modifications, in the greatest number and of the highest grade of organization, is past; and, since the extinction of the Dinosaurian order, it has been declining. The Reptilia are now in great part superseded by higher classes: Pterodactyles have given way to Birds; Megalosaurs and Iguanodons to carnivorous and herbivorous mammalia; but the sudden extinction of the one, and the abrupt appearance of the other, are alike inexplicable on any known natural causes or analogies.

New species, genera, and families of Reptiles have constantly succeeded each other, since the earliest periods in which the remains of this class can be discerned; but the change has been, upon the whole, from the complicated to the simple.

The Batrachian order, which is first indicated by the large and powerful Crocodiloid *Labyrinthodonts*, has dwindled down to the diminutive and defenceless Anourans and the fish-like Perennibranchians. The Saurian order was anciently represented by Reptiles manifesting the Crocodilian grade of organization under a rich variety of modifications and with great development of bulk and power: it has now subsided into a swarm of small Lacertians, headed by so few examples of the higher or loricate species, that it is no marvel such relics of a once predominating group should have found a humble place in Linnæus's Catalogue of Nature as coordinate members of the genus *Lacerta*.

Nevertheless some general analogies may be traced between the phænomena of the succession of Reptiles as a class, and those observed in the development of an individual reptile from the ovum. Thus the Embryonic structure of the vertebræ of the existing Crocodiles accords with the biconcave type; and this is exchanged, in the development of the individual as in the succession of species, for the ball-and-socket structure as the latest condition.

The almost universal prevalence of the more or less biconcave structure of the vertebræ of the earlier reptiles thus establishes a most interesting analogy between them and the earlier stages of growth of existing reptiles.

A similar analogy has been pointed out by M. Agassiz, between the heterocercal fishes, which exclusively prevail in the oldest fossiliferous strata, and the embryos of existing homocercal fishes, which seem to pass through the heterocercal stage.

The superior number of loricate Reptiles, and the more complete development of the dermal armour in the Crocodilian genera *Steneosaurus*, *Teleo-*

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* For the proof of the often doubted mammalian character of the *Thylacotherium* and *Phascolotherium* of the Stonesfield slate, the reader is referred to the Memoirs in the Sixth Volume of the Second Series of the Geological Transactions, pp. 47–58.

saurus, *Goniopholis*, &c., of the Oolitic and Wealden strata, corresponds with the prevalence of the well-mailed Ganoid order of fishes in the same formations.

The fossil reptiles, like the fossil fishes, approximate nearest to existing species in the tertiary deposits, and differ from them most widely in strata whose antiquity is highest.

Not a single species of fossil reptile now lives on the present surface of the globe.

The characters of modern genera cannot be applied to any species of fossil reptile in strata lower than the tertiary formations.

No reptile, with vertebræ articulated like those of existing species, has been discovered below the chalk.

Some doubt may be entertained as to whether the *Ichthyosaurus communis* did not leave its remains in both oolitic and cretaceous formations, but with this exception no single species of fossil reptile has yet been found that is common to any two great geological formations.

The evidence acquired by the researches which are detailed in the body of this Report, permits of no other conclusion than that the different species of Reptiles were suddenly introduced upon the earth's surface, although it demonstrates a certain systematic regularity in the order of their appearance. Upon the whole they make a progressive approach to the organization of the existing species, yet not by an uninterrupted succession of approximating steps. Neither is the progression one of ascent, for the Reptiles have not begun by the perennibranchiate type of organization, by which, at the present day, they most closely approach fishes; nor have they terminated at the opposite extreme, viz. at the Dinosaurian order, where we know that the Reptilian type of structure made the nearest approach to Mammals.

Thus, though a general progression may be discerned, the interruptions and faults, to use a geological phrase, negative the notion that the progression has been the result of self-developing energies adequate to a transmutation of specific characters; but, on the contrary, support the conclusion that the modifications of osteological structure which characterize the extinct Reptiles, were originally impressed upon them at their creation, and have been neither derived from improvement of a lower, nor lost by progressive development into a higher type.

The general progressive approximation of the animal kingdom to its present condition has been, doubtless, accompanied by a corresponding progress of the inorganic world; and thus, the differences which comparative anatomy demonstrates to have existed between the vertebrated inhabitants of the secondary epochs of the geological history of the earth, and the tertiary and present periods, form legitimate grounds for speculation, not only on the essential nature and causes of those differences, but upon the progressive changes to which our planet and its atmosphere may have been subject. For whether there had been grounds for regarding the organic phænomena of primæval times as earlier stages in the progressive development and transmutation of species, or whether, as the closest investigation of these phænomena seems to demonstrate, they have been the result of expressly created and successively introduced species,—they naturally lead the physiologist to speculate on the varying conditions of the surrounding media to which such organic differences may have related.

Now Reptiles mainly and essentially differ from Birds and Mammals in the less active performance of the respiratory function, and in a lower and simpler structure of the lungs and heart, whereby they become, so to say, less dependent on the atmosphere, or oxygen, for existence. From their extraordinary prevalence in the secondary periods, under varied modifications of size and structure, severally adapting them to the performance of those tasks in the economy of organic nature which are now assigned to the warm-blooded and quick-breathing classes, the physiologist is led to conjecture that the atmosphere had not undergone those changes, which the consolidation and concentration of certain of its elements in subsequent additions to the earth's crust may have occasioned, during the long lapse of ages during which the extinction of so large a proportion of the Reptilian class took place. And if the chemist, by wide and extended views of his science in relation to geology and mineralogy, should demonstrate, as the botanist, from considerations of the peculiar features of the extinct Flora has been led to suspect, that the atmosphere of this globe formerly contained more carbon and less oxygen than at present, then the anatomist might, *à priori*, have concluded that the highest classes of animals suited to the respiration of such a medium must have been the cold-blooded fishes and reptiles.

And besides the probability of such a condition of the zoological series being connected with the chemical modifications of the air, the terrestrial Reptiles, from the inferior energy of their muscular contractions, and still more from the greater irritability of the fibres and power of continuing their actions, would constitute the highest organized species, best adapted to exist under greater atmospheric pressure than operates on the surface of the earth at the present time.

Through such a medium approaching in a corresponding degree to the physical properties of water, a cold-blooded animal might even rise above the surface and wing its heavy flight, since this would demand less energetic muscular actions than are now requisite for such a kind of locomotion; and thus we may conceive why the atmosphere of our planet, during the earlier oolitic periods, may have been traversed by creatures of no higher organization than Saurians. If we may presume to conjecture that atmospheric pressure has been diminished by a change in the composition as well as by a diminution of the general mass of the air, the beautiful adaptation of the structure of birds to a medium thus rendered both lighter and more invigorating, by the abstraction of carbon and an increase of oxygen, must be appreciable by every physiologist. And it is not without interest to observe, that the period when such change would be thus indicated by the first appearance of birds in the Wealden strata*, is likewise characterized by the prevalence of those Dinosaurian Reptiles which in structure most nearly approach Mammalia, and which, in all probability, from their correspondence with Crocodiles in the anatomy of the thorax, enjoyed a circulation as complete as that of the Crocodile when breathing freely on dry land†.

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* Foot-prints alone, like those termed 'Ornithichnites,' observed in the New Red Sandstone of Connecticut, are insufficient to support the inference of the possession of the highly developed organization of a bird of flight by the creatures which have left them. The Rhynchosaur and biped Pterodactyles already warn us how closely the ornithic type may be approached without the essential characters of the Saurian being lost. By the Chirotherian Ichnolites we learn how closely an animal, in all probability a Batrachian, may resemble a pedimanous mammal in the form of its foot-prints.

The degree in which flying insects can resist noxious gases, which would be quickly fatal to the warm-blooded Vertebrates, invalidates the objection to a progressive change of atmosphere having accompanied the prevalence of quick-breathing animals, which might be suggested by the *Libellulæ* of the lias and by the oolitic Beetles.

† All existing Reptiles, which have the ribs at the anterior part of the thorax united by a head and tubercle to the centrum and neurapophysis of the vertebræ, have a heart with two distinct ventricles as well as two auricles. The contiguous aortæ arising from the two ventricles intercommunicate by an aperture so placed as to be covered by the sigmoid valves

The first indications of the warm-blooded classes, it might be anticipated, would appear, if introduced into the Reptilian era, under the form of such small insectivorous mammals, as are known at the present day to have a lower amount of respiration than the rest of the class; and the earliest discovered remains of mammalia, as, for example, those in the Stonesfield oolite, are actually the jaws of such species, with which are combined the characters of that order, Marsupialia, which is most nearly related to the oviparous Vertebrata.

The present speculations are, however, offered with all due diffidence; the collection of the evidence requisite for pursuing them to a semblance even of demonstration is only just begun, and they are thrown out with no other expectation of utility than as incentives to the chemical considerations of the nature and possibilities of such atmospheric changes as may be physiologically connected with the variations of organic nature made known by the researches of the anatomist.

A too cautious observer would, perhaps, have shrunk from such speculations, although legitimately suggesting themselves from the necessary relations between the organs and media of respiration; but the sincere and ardent searcher after truth, in exploring the dark regions of the past, must feel himself bound to speak of whatever a ray from the intellectual torch may reach, even though the features of the object should be but dimly revealed.

when blood is transmitted equally through them. When the amphibious Crocodile suffers an interruption in the pulmonary circulation by continued submersion, the aorta from the left ventricle, by the communication above mentioned, receives venous blood from the overcharged cavities of the right side of the heart; but when respiration is in full vigour on dry land, an undiluted stream of arterial blood is transmitted through the left aorta to the head and anterior extremities. The Dinosaurs, having the same thoracic structure as the Crocodiles, may be concluded to have possessed a four-chambered heart; and, from their superior adaptation to terrestrial life, to have enjoyed the function of such a highly-organized centre of circulation in a degree more nearly approaching that which now characterizes the warm-blooded Vertebrata.

ERRATA.

Page 64, 14 lines from bottom, *for* 'Cœlospondylian' *read* 'Amphicœlian.'
—— 67, 25 lines from top, *for* 'bifurcate' *read* 'biporcate.'
—— 88, after the 3rd line from top, insert 'with convexo-concave vertebræ.'
—— 104, 14 lines from bottom, *for* 'Clœospondylian' *read* 'Amphicœlian.

Reports on the Determination of the Mean Value of Railway Constants.

NOTICE.

The two following Reports, as well as the Report by Dr. Lardner on the same subject, already published in the Reports of the British Association for 1838, have been furnished in compliance with the request of the Committee to whom the superintendence of the experiments and the grants of money for the purpose of ascertaining the amount of railway constants was entrusted by the British Association.

The Committee originally appointed in 1837 consisted of Mr. H. Earle, Dr. Lardner, Mr. Locke, Mr. Rennie, and Mr. Macneil, to these Mr. Edward Woods was subsequently added.

The engagements of the various members of the Committee prevented them from giving that personal and individual attention to the experiments which were so highly desirable, and but for the continued and indefatigable exertions of Dr. Lardner, Mr. H. Earle, and Mr. E. Woods, the object of the Association could never have been carried out.

Of the two following Reports, the one is in continuation and conclusion of that which has already appeared by Dr. Lardner; the other is a separate and independent Report by Mr. E. Woods, referring partly to the same and partly to a great number of additional experiments.

The Report of Mr. E. Woods, while it agrees in many important particulars, differs in others from the Reports of Dr. Lardner, and, when viewed as a whole, is somewhat different both in its structure and in the manner in which the conclusions are arrived at, deduced, and reasoned upon.

Under these circumstances, the Committee of the Mechanical Section of the British Association at Plymouth were of opinion that the objects of the Association would be best fulfilled by the publication of both; the results in which both agree will be looked upon as extremely valuable both by the theoretical and practical man, while those in which they differ will form subjects of great interest for future inquiry.

Second and concluding Report on the Determination of the Mean Value of Railway Constants. By Dionysius Lardner, LL.D., F.R.S., &c.

By reference to the former part of this Report, it will be perceived that among the points which remained for further experimental inquiry the principal were the following:

1. Whether the presence of the engine and tender in front of the train has any effect in rendering the resistance to the progressive motion of the train, arising from friction or atmospheric resistance, or both of these combined, less than it would be if the train were moved forward with the front of the foremost coach presented directly to the air.

2. Whether the *form* of the front of the train produces any sensible effect on the resistance, or whether any advantage can be gained by the adoption of a pointed front like the bow of a ship.

3. Whether, in moving down an inclined plane by gravity, the resistance

of the air acting against the foremost carriage has a greater effect in throwing the succeeding carriages out of square than it would have if the train were preceded by the engine and tender.

4. In what manner the resistance would be modified by increasing the length and weight of the train.

These questions have severally arisen out of objections urged against the experiments detailed in the former part of this Report, and against the validity of the consequences therein deduced from them, by Mr. I. K. Brunel, the engineer of the Great Western Railway, in a report addressed to the directors of that company.

Although, from the general experience of the writer of this Report and of the other members of the Committee, it appeared that none of these various objections had much weight, it was considered right to bring them to the immediate test of experiment.

It was first objected, "That the circumstances under which the experiments "were performed were not really, though they were *apparently*, similar to "those of any ordinary train in motion; that the carriages in these experi"ments were sent with the square end foremost to meet and receive the full "resistance due to their surface, which is totally different from the case in "which the engine precedes them." The engine in front, it was stated, would act as a cut-air or bow, and thus destroy or diminish the resistance produced by the flat front of the carriage moving foremost.

In order to ascertain the force of this objection, the following experiment was made.

An engine called the "Fury" was reduced as nearly as possible to the condition of an ordinary carriage, by detaching from the axles and removing from the engine the connecting rods, pistons, working gear, and every moving part which could produce any mechanical resistance different from that to which an ordinary coach would be subject. Two coaches were also procured, and so loaded as to be exactly equal in weight with the engine and tender.

The engine and tender were then placed at the summit of the Sutton inclined plane on the Liverpool and Manchester Railway, which falls 1 in 89, for about a mile and a half, and were allowed to descend the plane by their gravity; the time of passing a succession of stakes dividing the plane into spaces of 110 yards, was noted.

The two coaches were next placed at the summit of the plane, and allowed in like manner to descend, and the circumstances of their descent observed in the same way.

Sutton Incline Plane.—Is laid with 60 lbs. rails, 3 feet bearings, on stone blocks: road has been recently relaid: posts are placed 110 yards, or one sixteenth of a mile apart: descent from No. 0 to No. 11 post is 3·63 feet per 110 yards =1 in 90·9: gravitating force is therefore 24·64 lbs. per ton: descent from No. 11 to No. 20 post is 3·71 feet per 110 yards = 1 in 88·5: gravitating force is therefore 25·31 lbs. per ton.

Whiston Incline Plane.—Was laid with 50 lbs. rails, 3 feet bearings, on stone blocks, about three years since: posts placed 110 yards, or one sixteenth of a mile apart: descent 1 in 96: gravitating force is therefore 23·33 lbs. per ton. A section of these planes is given in fig. 1. Plate I. A breeze from W.N.W.: a drizzling rain: rails quite wet, and in good order for travelling.

The details of these two experiments were as follows:—

Experiment with "Fury" and Tender.

	cwts.	qrs.	lbs.
"Fury" engine	147	3	0
Tender.	75	0	0
Load	5	0	0
Gross weight . . .	227	3	0

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.	Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.
Yds.		h m s				Yds.		h m s			
0	0	8 11 1				2420	22	8 15 46·5	8	8	28·12
110	1	59	58	………	3·88	2530	23	54·5	8		
220	2	12 22	23	………	9·78	2640	24	16 3	8·5	8·5	26·47
330	3	40	18	………	12·50	2750	25	11·5	8·5		
440	4	55	15	………	15·00	2860	26	21	9·5	………	23·68
550	5	13 9	14	………	16·07	2970	27	31	10	………	22·50
660	6	21·5	12·5	12·5	18·00	3080	28	41·5	10·5	………	21·43
770	7	34	12·5			3190	29	52·5	11	………	20·45
880	8	44·5	10·5	10·5	21·43	3300	30	17 4·5	12·25	12·00	18·75
990	9	55	10·5			3410	31	16·25	11·75		
1100	10	14 5	10	………	22·50	3520	32	29·75	13·5	………	16·66
1210	11	14·5	9·5	9·5	23·68	3630	33	44·25	14·5	………	15·51
1320	12	24	9·5			3740	34	59	14·75	………	15·25
1430	13	33	9	………	25·00	3850	35	18 15	16	………	14·06
1540	14	41·5	8·5	8·5	26·47	3960	36	33	18	………	12·50
1650	15	50·5	9			4070	37	53	20	………	11·25
1760	16	58·5	8			4180	38	19 13·5	20·5	………	10·97
1870	17	15 7	8·5	8·25	27·27	4290	39	38	24·5	………	9·18
1980	18	15	8			4400	40	20 4	26	………	8·65
2090	19	22·25	7·25	7·75	29·03	4510	41	35·5	31·5	………	7·14
2200	20	30·5	8·25			4620	42	21 17	41·5	………	6·14
2310	21	38·5	8·0		28·12	4710		22 38	81	………	

Experiment with two Coaches.

Two First Class Carriages.

	cwts.	qrs.	lbs.
Caledonian	116	3	0
Earl of Derby	110	0	0
	226	3	0

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.	Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.
Yds.		h m s				Yds.		h m s			
0	0	9 23 0									
110	1	53·25	53·25	………	4·22	880	8	9 25 36·75	10·75	10·75	20·94
220	2	24 15	21·75	………	10·35	990	9	47·5	10·75		
330	3	33·5	18·5	………	12·16	1100	10	57	9·5	9·75	23·08
440	4	48·75	15·25	………	14·75	1210	11	26 7	10		
550	5	25 2	13·25	………	16·98	1320	12	16	9	9·00	25·00
660	6	14·25	12·25	………	18·36	1430	13	25	9		
770	7	26	11·75	………	19·14	1540	14	34	9		

TABLE (*Continued*).

Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.	Dist.	Posts.	Times.	Diffs.	Average Diffs.	Miles per hour.
Yds.		h m s				Yds.		h m s			
1650	15	9 26 42·5	8·5	8·62	26·10	3190	29	9 28 49	11·75	....	19·14
1760	16	51·25	8·75			3300	30	29 1	12	....	18·75
1870	17	59·25	8	8·00	28·12	3410	31	13·5	12·5	....	18·00
1980	18	27 7·25	8			3520	32	27·25	13·75	....	16·36
2090	19	15·75	8·5	8·25	27·26	3630	33	42	14·75	....	15·25
2200	20	23·75	8			3740	34	58	16	....	14·06
2310	21	32	8·25	....	27·26	3850	35	30 15·5	17·5	....	12·86
2420	22	39·75	7·75	8·33	27·00	3960	36	35·25	19·75	....	11·39
2530	23	48·25	8·5			4070	37	57	21·75	....	10·35
2640	24	57	8·75			4180	38	31 21·25	24·25	....	9·27
2750	25	28 6·5	9·5	9·5	23·68	4290	39	50	28·75	....	7·82
2860	26	16	9·5			4400	40	32 22·5	32·5	....	6·92
2970	27	26·5	10·5	....	21·43	4510	41	33 7	44·5	....	5·06
3080	28	37·25	10·75	....	20·94	4577		34 40	93		

The general results of these two experiments are placed in juxtaposition in the following table:—

	Weight.	Total distance run.	Time of running total distance.	Greatest speed.	Time of descending the Sutton plane 0 to 20.
	Tons.	Yards.	m s	Miles per hour.	m s
Fury and Tender	11·39	4710	11 37	29	4 29
Two Coaches ...	11·33	4577	11 40	28·12	4 24
Difference...	·06	133	0 3		0 5

It appears, therefore, that the difference in the whole distance run by the two coaches and by the engine and tender, amounted to only 133 yards in a distance little short of three miles; and there was only three seconds difference in the time which elapsed between the moment of starting and the moment of coming to rest. The maximum speed was the same, and the times of descending the inclined plane differed by only five seconds. The difference, such as it was, was in favour of the coaches. In fact the differences of the numbers in the successive columns are only such as would take place in the same experiment twice repeated with the same coaches.

As a further experimental test of this point, the engine and tender were now placed in front of a train of four coaches, and were allowed to descend the plane in the same manner. The engine and tender were then removed, and replaced by two coaches of equal weight, and the train of six coaches was allowed to descend the plane in the same manner. The details of these experiments are as follows:—

Engine, Tender, and four First Class Carriages, viz.

		cwts.	qrs.	lbs.
Fury Tender	. . . .	222	3	0
Clarence Sovereign Traveller Telegraph	. . . .	326	3	4
	Gross weight . .	549	2	4

Dist.	Posts.	Times.			Diffs.	Average Diffs.	Miles per hour.
Yds.		h	m	s			
0	0	3	30	30			
110	1		31	29	59	……	3·81
220	2			54	25	……	9·00
330	3		32	12	18	……	12·50
440	4			28	16	……	14·06
550	5			42	14	……	16·07
660	6			55	13	……	17·30
770	7		33	7	12	……	18·75
880	8			18	11	……	20·45
990	9					10·5	21·43
1100	10			39	21·2		
1210	11			48·5	9·5	9·5	23·68
1320	12			58	9·5		
1430	13		34	7	9	8·75	25·72
1540	14			15·5	8·5		
1650	15			24	8·5	8·50	26·47
1760	16			32·5	8·5		
1870	17			40·5	8	8·12	27·68
1980	18			48·75	8·25		
2090	19			56	7·25	7·37	30·50
2200	20		35	3·5	7·5		
2310	21			11·25	7·75	7·67	29·34
2420	22			19	7·75		
2530	23			26·5	7·5		
2640	24	3	35	34·5	8	……	28·12
2750	25					8·75	25·72
2860	26			52	17·5		
2970	27		36	0·5	8·5	8·87	25·34
3080	28			9·75	9·25		
3190	29			19	9·25	……	24·32
3300	30			29·25	10·25	……	21·94
3410	31			40	10·75	……	20·94
3520	32			51·25	11·25	11·00	20·45
3630	33		37	2	10·75		
3740	34			14	12	……	18·75
3850	35			27	13	13·00	17·30
3960	36			40	13		
4070	37			54·5	14·5	14·50	15·51
4180	38		38	9	14·5		
4290	39			25	16	……	14·06
4400	40			42	17	……	13·23
4510	41		39	0·5	18·5	……	12·16
4620	42			20	19·5	……	11·54
4730	43			43	23	……	9·78
4840	44		40	11	28	……	8·04
4950	45			50	39	……	5·78
5060	46		42	11	81	……	2·78
5068				39	28		

			cwts.	qrs.	lbs.			cwts.	qrs.	lbs.
Six First Class Carriages, viz.	Express	.	93	0	24	Sovereign	.	90	2	24
	Herald	.	91	1	24	Traveller	.	91	2	24
	Clarence	.	88	3	24	Telegraph	.	93	1	24

Gross weight . 549 cwts. 2 qrs. 4 lbs.

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.	Average Diffs.	Miles per hour.
Yds.		h	m	s			
0	0	12	5	30			
110	1		6	26	56	……	4·02
220	2			50	24	……	9·37
330	3		7	8·5	18·5	……	12·16
440	4			25	16·5	……	13·63
550	5			38·5	13·5	……	16·66
660	6			51·5	13	……	17·30
770	7		8	3	11·5	……	19·56
880	8			14	11	……	20·45
990	9			24·25	10·25	10·25	21·94
1100	10			34·5	10·25		
1210	11			44	9·5	……	23·68
1320	12			53	9	9·00	25·00
1430	13		9	2	9		
1540	14			10·25	8·25	8·50	26·47
1650	15			19	8·75		
1760	16			27	8	8·00	28·12
1870	17			35	8		
1980	18			43	8	7·75	29·02
2090	19			50·5	7·5		
2200	20			58	7·5	7·25	31·03
2310	21		10	5	7		
2420	22			13	8	7·62	29·5
2530	23			20·25	7·25		
2640	24	12	10	28·5	8·25	8·12	27·68
2750	25			36·5	8		
2860	26			45·5	9	9·00	25·00
2970	27			54·5	9		
3080	28		11	3·5	9		
3190	29			13	9·5	……	23·68
3300	30			23	10	……	22·50
3410	31			35·5	12·5	10·5	21·43
3520	32			44	8·5		
3630	33			55	11	……	20·45
3740	34		12	7	12	……	18·75
3850	35			20	13	……	17·30
3960	36			33·25	13·25	……	16·98
4070	37			48	14·75	……	15·25
4180	38		13	3	15	……	15·00
4290	39			19·5	16·5	……	13·63
4400	40			38·5	19	……	11·84
4510	41			59	20·5	……	10·97
4620	42		14	23·5	24·5	……	9·18
4730	43			54·5	31	……	7·26
4840	44		15	51	56·5	……	3·98
4850	…		16	18	……		

Transverse sections of the engine and the coaches are given in figs. 2 and 3. Plate I.

The general results of these experiments are here shown in juxtaposition :—

	Weight.	Total distance.	Time of running total distance.		Greatest speed.	Time of descending Sutton Plane.	
	Tons.	Yards.	m	s	Miles per hour.	m	s
Fury, tender, and four coaches...	27·45	5068	12	9	30·5	4	33
Six coaches.........	27·45	4850	10	48	31	4	28
Difference......		218	1	21			5

It is evident from these results, independently of other experiments which will be presently stated, that the form of the front, whether flat or sharp, has no observable effect on the resistance; and that whether the engine and tender be in front, or two carriages of the same weight, the motion of the train and the resistance to its motion will be exactly the same.

The form of a boat or beak having been given to some of the engines on one of the lines of railway, and the advantages attending such a form in diminishing the resistance having much insisted on, it was determined to ascertain its effect by direct experiment.

For this purpose a sharp end was constructed to be attached in front of the foremost carriage, consisting of two boards equal in height to the body of the carriage, and which being attached to each corner, were united in front at an angle, the vertex of the angle being five feet six inches before the flat front of the carriage, and the base of the angle being six feet six inches, corresponding with the width of the carriage. Thus, instead of presenting a flat surface to the air, the carriage having this apparatus attached would present a wedge to it, which would have the effect of a cut-air.

This contrivance was first tried with a single coach, which, having it attached in front, was moved as before down the Sutton Plane; and the circumstances of the motion having been observed and recorded, the wedge was removed, and the coach again moved down the plane with its flat end presented to the air. The following are the results of these experiments :—

	Weight.	Total distance run.	Time of running total distance.		Greatest velocity.	Time of descending Sutton Plane 1 in 89.	
	Tons.	Yards.	m	s	Miles per hour.	m	s
Coach with pointed front	5·35	3975	11	0	24·3	5	35
Coach with flat front............	5·35	3905	11	0	23·7	4	45
Difference......		70				0	50

This result shows that the form of the front produced no effect on the resistance.

It was determined to remove all possible doubt on this point by varying the circumstances of the experiment. A train of eight coaches was accordingly prepared and brought to the series of inclined planes at Madeley on the Grand Junction Railway, the section and curves of which have been described in the first part of this Report. This train was first moved down the planes with the pointed end attached, and afterwards without that appendage. The details of these two experiments were as follows:—

July 11th, 1839.—EXPERIMENT No. I.

Eight Second Class Carriages, No. 12, 35, 5, 22, 9, 29, 30, 20.

	tons.	cwts.	qrs.
Weight of Carriages and Load	40	0	0
Ten Passengers		15	0
Gross weight . . .	40	15	0

Pointed end placed in front.

Initial velocity 23·71 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.	Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s				Yards.		h	m	s			
	61	8	27	36·5					21	8	33	18·5	8·5	34·25	23·89
	60			46·5	10				20			27	8·5		
	59			55·75	9·25				19			36	9		
	58		28	4·25	8·5				18			44·75	8·75		
0	57			13	8·75	36·5	22·41	4000	17			53·25	8·5	34·75	23·54
	56			22	9				16		34	2	8·75		
	55			30·25	8·25				15			10	8		
	54			39	8·75				14			19	9		
	53			47·5	8·5	34·5	23·71		13			27	8	33·75	24·24
500	52			56	6·5			4500	12			36	9		
	51		29	5	9				11			44	8		
	50			13	8				10			53·25	9·25		
	49			22	9	34·5	23·71		9		35	1·75	8·5	34·75	23·54
	48			30	8				8			10	8·25		
1000	47			39	9			5000	7			18	8		
	46			47·5	8·5				6			27	9		
	45			56·25	8·75	34·25	23·89		5			35·25	8·25	33·5	24·42
	44		30	4·25	8				4			44	8·75		
	43			13·25	9				3			52·75	8·75		
1500	42			21·75	8·5			5500	2		36	1	8·25		
	41			30	8·25	33·75	24·24		1			9	8	33·75	24·24
	40			38·5	8·5				0			17·75	8·75		
	39			47·25	8·75				1			26	8·25		
	38			55·25	8				2			34·5	8·5		
2000	37		31	3	7·75	33	24·79	6000	3			43	8·5	34	24·06
	36			12·25	9·25				4			52	9		
	35			20·25	8				5		37	0	8		
	34			...	8·25				6			9·25	9·25		
	33			37	8·5	34	24·06		7			18	8·75	35	23·37
2500	32			46	9			6500	8			27·5	9·5		
	31			54	8				9			36·5	9		
	30		32	2	8				10			46	9·5		
	29			10	8	33	24·79		11			55·5	9·5	37·5	21·81
	28			18·25	8·25				12		38	4·5	9		
3000	27			...	8·5			7000	13			14	9·5		
	26			35·25	8·5				14			23·5	9·5		
	25			44·25	9	34·25	23·89		15			33	9·5	37·5	21·81
	24			53	8·75				16			42·5	9·5		
	23		33	1·25	8·25				17			52·5	10·0		
3500	22			10	8·75										

EXPERIMENT No. I. (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards		h m s			
7500	18	8 39 1·75	9·25				50	8 44 26	10·5		
	19	11·5	9·75	38·5	21·25		51	36·5	10·5	41·5	19·71
	20	21·25	9·75				52	47·5	11		
	21	31	9·75			11,000	53	58	10·5		
	22	41	10				54	45 8·25	10·25		
8000	23	51	10	39·5	20·71		55	19	10·75	42·5	19·25
	24	40 0·75	9·75				56	29·5	10·5		
	25	10·5	9·75				57	40·5	11		
	26	20·5	10			11,500	58	51·75	11·25		
	27	30·25	9·75	39·25	20·84		59	46 2	10·25	43	19·02
8500	28	40	9·75				60	13·25	11·25		
	29	50·25	10·25				61	24·5	11·25		
	30	41 0·25	10				62	35·75	11·25		
	31	10	9·75	39·75	20·58	12,000	63	47·5	11·75	45·5	17·98
	32	20·5	10·5				64	59·25	11·75		
9000	33	30·5	10				65	47 11	11·75		
	34	41	10·5				66	23	12		
	35	51·25	10·25	41·25	19·86		67	35	12	47·5	17·22
	36	42 1·25	10			12,500	68	47·25	12·25		
	37	11·25	10				69	59·25	12		
9500	38	21·75	10·5				70	48 12·25	13		
	39	32·25	10·5	41	19·95		71	24·5	12·25	49·5	16·53
	40	42·5	10·25				72	37·75	13·25		
	41	53·25	10·75			13,000	73	51·25	13·5		
	42	43 3	9·75				74	49 4	12·75		
10,000	43	13·25	10·25	41	19·95		75	...	13·25	52·75	15·51
	44	23·75	10·5				76	31	13·75		
	45	34	10·25				77	44·75	13·75		14·87
	46	44·75	10·75			13,500	78	58·5	13·75		
	47	55	10·25	41·75	19·60	14,411		54 24·5			*
10,500	48	44 5·25	10·25								
	49	15·5	10·25								

Breeze down the Plane.

* Stopped.

July 11th, 1839.—Experiment No. II.

Eight Second Class Carriages as before.

	tons.	cwts.	qrs.
Weight of Carriage and Load	40	0	0
Ten Passengers		15	0
Gross weight . .	40	15	0

Pointed end taken off.

From initial velocity 23·37 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	61	9	37	43			
	60			53·5	10·5		
	59		38	3	9·5		
	58			12·5	9·5		
0	57			21·25	8·75	38·25	21·39
	56			30	8·75		
	55			38	8		
	54			46	8		
	53			53·25	7·25	32	25·57
500	52		39	0	6·75		
	51			...	7·5		
	50			15	7·5		
	49			22·5	7·5	29·25	27·97
	48			29·5	7		
1000	47			36·5	7		
	46			44·25	7·75		
	45			51·5	7·25	29	28·21
	44			58·5	7		
	43		40	5·75	7·25		
1500	42			13·25	7·5		
	41			20·5	7·25	29	28·21
	40			27·75	7·25		
	39			35·25	7·5		
	38			43	7·75		
2000	37			50·25	7·25	29·75	27·50
	36			57·25	7		
	35		41	4·5	7·25		
	34			12	7·5		
	33			19·25	7·25	29	28·21
2500	32			27	7·75		
	31			34·5	7·5		
	30			42	7·5		
	29			49·25	7·25	30	27·27
	28			57	7·75		
3000	27		42	4	7		
	26			12·25	8·25		
	25			19·75	7·5	30·5	26·82
	24			27·5	7·75		
	23			35	7·5		
3500	22			43	8		
	21			51·25	8·27	31·5	25·97
	20			58·5	7·25		
	19		43	6·5	8		

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	18	9	43	14·25	7·75		
4000	17			22·25	8	31	26·39
	16			30·25	8		
	15			38	7·75		
	14			46·25	8·25		
	13			...	7·75	31·75	25·77
4500	12		44	2	8		
	11			9·75	7·75		
	10			18	8·25		
	9			25·75	7·75	31·75	25·77
	8			33·5	7·75		
5000	7			41·25	7·75		
	6			49·5	8·25		
	5			57	7·5	31·25	26·18
	4		45	5	8		
	3			13	8		
5500	2			20·5	7·5		
	1			28·25	7·75	31·25	26·18
	0			36	7·75		
	1			44	8		
	2			52	8		
6000	3		46	0	8	31·75	25·76
	4			7·75	7·75		
	5			16	8·25		
	6			24	8		
	7			33	9	33	24·79
6500	8			41	8		
	9			50	9		
	10			58·5	8·5		
	11		47	7	8·5	34	24·06
	12			15·5	8·5		
7000	13			24·5	9		
	14			33	8·5		
	15			42	9	35	23·37
	16			51·25	9·25		
	17		48	0·25	9		
7500	18			...	8·75		
	19			18	9	36	22·73
	20			27·25	9·25		
	21			36·5	9·25		
	22			46	9·5		
8000	23			55·5	9·5	37·5	21·81

EXPERIMENT No. II. (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	24	9	49	4·25	8·75		
	25			14·5	10·25		
	26			24·5	10		
	27			31·5	7	36	22·73
8500	28			43	11·5		
	29			52·75	9·75		
	30		50	2·5	9·75		
	31			12	9·5	40·5	20·20
	32			22·25	10·25		
9000	33			32·25	10		
	34			42·25	10		
	35			52·5	10·25	40·5	20·20
	36		51	2	9·5		
	37			12·25	10·25		
9500	38			22·25	10		
	39			32·25	10	39·75	20·58
	40			42·5	10·25		
	41			52·75	10·25		
	42		52	3	10·25		
10,000	43			13·25	10·25	41	19·95
	44			23·25	10		
	45			34	10·75		
	46			44·25	10·25		
	47			54·5	10·25	41·25	19·83
10,500	48		53	5	10·5		
	49			15	10		
	50			26	11		
	51			36·5	10·5	42	19·48
	52			47·25	10·75		
11,000	53			58	10·75		
	54		54	8·25	10·25		

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	55	9	54	19	10·75	42·5	19·25
	56			29·75	10·75		
	57			40·5	10·75		
11,500	58			52	11·5		
	59		55	2·5	10·5	43·5	18·81
	60			13·75	11·25		
	61			25·25	11·5		
	62			36·5	11·25		
12,000	63			48·75	12·25	46·25	17·69
	64		56	0·5	11·75		
	65			12·5	12		
	66			24·5	12		
	67			37	12·5	48·25	16·96
12,500	68			50	13		
	69		57	2·5	12·5		
	70			15	12·5		
	71			28·5	13·5	51·5	15·89
	72			41·75	13·25		
13,000	73			55·5	13·75		
	74		58	9	13·5		
	75			...	13·5	54	15·15
	76			36·5	14		
	77			51	14·5		
13,500	78		59	5	14		
13,598				19·5	14·5	57	14·35
13,785				51·5		*	
13,915		10	0	16			
14,242			1	53·5			
14,331			3	22			

Breeze down the Plane.

* Stopped.

The general results of these two experiments are here exhibited in juxtaposition.

	Weight.	Total distance run.	Time of running total distance.	Initial Speed.	Uniform speed on 1 in 177.	Speed at foot of 1 in 265.	Speed at foot of 1 in 330.	Time of moving down 1 in 177.	Time of moving down 1 in 265.	Time of moving round 1 in 330.
	Tons.	Yards.	m s	Miles per hr.	Miles per hr.	Miles per hr.	Miles per hr.	m s	m s	m s
Train with pointed end foremost.	40·75	14,411	26 48	23·70	24·	19·25	14·87	8 41	8 50	4 50
Same train in its ordinary state.	40·75	14,331	25 39	23·37	26·18	19·25	14·35	7 53	9 32	4 57
Difference		80	1 9	0·33	2·18		0·52	0 48	0 42	0 7

It appears, therefore, that the distance run with the wedge foremost differed only 80 yards in a distance of about *eight miles* from that through which the same train ran with its flat front. This and the other differences indicated in the table are evidently such only as would take place with the same experiment twice repeated with the same carriages.

With a view to ascertain how far mere magnitude of frontage, independently of the general magnitude of the train, is productive of resistance, the front of a coach was enlarged by boards extending from either side to a distance of about twenty inches, adding about twenty-four square feet to the front surface, and forming a sort of wings in front of the carriage, but no corresponding width being given to any other part of the carriage. The coach thus prepared was placed at the summit of the Sutton plane, and allowed to descend from a state of rest. It was then brought back to the summit and the wings removed, and was allowed to descend in its ordinary state. The result of these two experiments was as follows:—

	Weight.	Total distance run.	Time of running that distance.		Greatest speed.	Time of moving down Sutton Plane 1-89.	
	Tons.	Yards.	m	s	m. per h.	m	s
Coach with enlarged front.	5·35	3,139	9	10	19·15	5	31
Coach with ordinary front.	5·35	3,289	9	2	21·45	4	15
Difference		150	0	8	2·30	1	16

From which it was inferred, that mere width of frontage, apart from the general increase of magnitude, was not productive of any considerable practical effect in increasing the resistance.

A strong impression existed in the minds of some engineers and scientific men, to whom the results of these experiments was communicated while they were in progress, that the shape of the hinder part of the train might have an effect upon the resistance. It was supposed that in very rapid motion a tendency to a vacuum would be produced behind the train, and that a corresponding atmospheric resistance, due to this partial vacuum, would be produced in front; that, consequently, if the square shape was removed from the hinder part, less resistance would be found. Although no great weight was attached to this, it was determined, nevertheless, to submit it to a trial, and with that view a train of three carriages was placed at the summit of the Sutton plane, falling $\frac{1}{89}$, and allowed to descend by gravity in their ordinary state. They were next allowed to descend, having the pointed end behind; they next descended with the pointed end before: and, lastly, they were once more allowed to descend without the pointed end. The result of these four experiments is given in the following table. (See Table, p. 216.)

In the third column is expressed the entire distance run, in yards; in the fourth column is the time of going that distance; in the fifth column is the speed acquired in descending the Sutton plane; in the sixth column the time of descending that plane; in the seventh column the time of moving a distance of $2\frac{1}{2}$ miles from the time of starting; and in the last column, the time of moving from the twelfth to the twenty-eighth stake, throughout which, the motion being tolerably rapid, the effect of the air might be expected to be greatest.

It is evident, from these experiments, that no modification of the resistance is produced by the form of either end of the train, at least within any practical limits, to which the variation of that form can be subject.

In order to ascertain whether the open spaces between the successive carriages forming the train had any effect upon the resistance, hooks were attached to the edges of the ends of the several coaches, by means of which canvas was stretched from coach to coach so as to cover in those open spaces, and convert the train into a single unbroken column. The train thus prepared was the same train of eight coaches used in the former experiments, and the following are the details of the experiments made on the Madeley planes.

	Weight.	Total distance run.	Time of running total distance.	Greatest speed.	Time of moving down Sutton Plane 1-89.	Time of moving 2¼ miles.	Time from stake 12 to stake 28.
	Tons.	Yards.	m s	m. per h.	m s	m s	m s
Three coaches, with flat front and end.	14·8	5,209	13 50	32·14	4 28	7 54	2 9
Same, with pointed end	14·8	5,350	13 45	31·03	4 25	7 50	2 9
Same, with pointed front...............	14·8	5,576	13 1	32·14	4 23	7 30	2 5
Same, with flat front and end....	14·8	5,518	13 25	32·14	4 22	7 32	2 6

July 11th, 1839.

Eight Second Class Carriages as before, the spaces between the Carriages being closed up with canvas.

	tons.	cwts.	qrs.
Weight of Carriage and Load....	40	0	0
Ten Passengers...................		15	0
Gross weight....	40	15	0

From initial velocity 25·57 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	61	12 17 44·25					44	12 19 57	7·25		
	60	53·5	9·25				43	20 4·5	7·5		
	59	18 2	8·5			1500	42	12	7·5		
	58	10	8				41	20	8·	30·25	27·05
0	57	17·75	7·75	33·5	24·42		40	27·75	7·75		
	56	25·25	7·5				39	35·25	7·5		
	55	33	7·75				38	43·25	8		
	54	40·5	7·5			2000	37	51·25	8	31·25	26·18
	53	48·75	8·25	31	26·39		36	58·5	7·25		
500	52	56	7·25				35	21 6	7·5		
	51	19 3·5	7·5				34	14	8		
	50	11·25	7·75				33	21·75	7·75	30·5	26·82
	49	19	7·75	30·25	27·05	2500	32	30	8·25		
	48	26·5	7·5				31	37·5	7·5		
1000	47	34·25	7·75				30	45·25	7·75		
	46	41·25	7				29	53·25	8	31·5	25·97
	45	49·75	8·5	30·75	26·61		28	22 1	7·75		

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
3000	27	12 22 8·5	7·5		
	26	16·5	8		
	25	24·5	8	31·25	26·18
	24	32·75	8·25		
	23	40·5	7·75		
3500	22	49	8·5		
	21	57	8	32·5	25·17
	20	23 5	8		
	19,	13	8		
	18	21·25	8·25		
4000	17	29·5	8·25	32·5	25·17
	16	38	8·5		
	15	46	8		
	14	54	8		
	13	24 1·75	7·75	32·25	25·37
4500	12	10	8·25		
	11	18	8		
	10	26	8		
	9	34	8	32·25	25·37
	8	42·25	8·25		
5000	7	50·25	8		
	6	58	7·75		
	5	25 6	8	32	25·57
	4	14	8		
	3	22	8		
5500	2	30	8		
	1	38	8	32	25·57
	0	46·25	8·25		
	1	54·25	8		
	2	26 2	7·75		
6000	3	10	8	32	25·57
	4	18	8		
	5	26·5	8·5		
	6	35	8·5		
	7	43·5	8·5	33·5	24·42
6500	8	52·25	8·75		
	9	27 0·5	8·25		
	10	9	8·5		
	11	18	9	34·5	23·71
	12	26·5	8·5		
7000	13	35·25	8·75		
	14	44·25	9		
	15	53·25	9	35·25	23·21
	16	28 1·5	8·25		
	17	10·5	9		
7500	18	19·25	8·75		
	19	28·75	9·5	35·5	23·05
	20	38	9·25		
	21	47·25	9·25		
	22	56·25	9		
8000	23	29 5·25	9	36·5	22·41
	24	14·25	9		
	25	24	9·75		
	26	34	10		
	27	43·5	9·5	38·25	21·39

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
8500	28	12 29 53.25	9·75		
	29	30 2·5	9·25		
	30	12·5	10		
	31	22·5	10	39	20·98
	32	33	10·5		
9000	33	42·5	9·5		
	34	53·25	10·75		
	35	31 3·25	10	40·75	20·07
	36	14	10·75		
	37	24·5	10·5		
9500	38	35·25	10·75		
	39	46·25	11	43	19·02
	40	57	10·75		
	41	32 7·75	10·75		
	42	18·5	10·75		
10,000	43	29·5	11	43·25	18·91
	44	40·25	10·75		
	45	51·75	11·5		
	46	33 2·5	10·75		
	47	13·75	11·25	44·25	18·49
10,500	48	25	11·25		
	49	36	11		
	50	48	12		
	51	59	11	45·25	18·08
	52	34 10	11		
11,000	53	21·25	11·25		
	54	33	11·75		
	55	44·5	11·5	45·5	17·99
	56	55·75	11·25		
	57	35 7·75	12		
11,500	58	19·25	11·5		
	59	32	12·75	47·5	17·22
	60	44	12		
	61	55·75	11·75		
	62	36 8	12·25		
12,000	63	21	13	49	16·69
	64	34·25	13·25		
	65	47·75	13·5		
	66	37 2	14·25		
	67	15	13	54	15·15
12,500	68	29	14		
	69	43·25	14·25		
	70	58	14·75		
	71	38 13	15	58	14·10
	72	28·25	15·25		
13,000	73	43·25	15		
	74	59	15·75		
	75	……	16	62	13·19
	76	39 31	16		12·78
	77	47·5	16·5		
13,500	78	40 4	16·5	……	12·39
13,598		22	18	……	11·36
13,785		41 5			
13,915		54·5			
13,967	*	42 53·25			

Breeze down the Plane.

On comparing the general results of this experiment with those of the same train in its ordinary state, we obtain the following comparative table of effects.

	Weight.	Total distance run.	Time of running total distance.	Initial speed.	Uniform speed on 1 in 177.	Speed at foot of 1 in 265.	Speed at foot of 1 in 330.	Time of moving down 1 in 177.	Time of moving down 1 in 265.	Time of moving down 1 in 330.
	Tons.	Yards.	m s	Miles per hr.	Miles per hr.	Miles per hr.	Miles per hr.	m s	m s	m s
Train with Canvas......	40·75	13,967	25 9	25·57	25·37	18·08	14·10	8 2	10 47	4 31
Train without Canvas......	40·75	14,331	25 39	23·37	26·18	19·25	14·35	7 53	9 32	4 57
Difference ...		364	30	2·20	0·81	1·17	0·25	0 9	1 15	0 26

These results prove that the open spaces between the coaches have no effect on the resistance.

On comparing the preceding experiments with those made with a train of waggons having high sides and ends capable of being taken down and laid flat upon them, it will be seen that although a change of frontage produce no observable effect on the resistance, a change in the entire *volume* or *bulk* of the train produces a very considerable effect on the resistance to the tractive power.

If that part of the resistance due to the air depend altogether, or chiefly, on the frontage of the train, it would follow that by increasing the extent of the train by additional coaches, that part of the resistance would receive either no augmentation, or would be inconsiderably increased. To reduce this to the test of experiment, it was accordingly determined to run trains of various magnitude down inclined planes till they should attain uniform velocities, and thereby discover the manner in which their resistance would be affected.

Experiments of this kind having been already made with trains of four coaches, and reported in the former part of this paper, it was now resolved to extend them to trains of six and eight coaches. The following are the results of these experiments, which in their details were conducted in all respects in the same manner as before.

Number of Coaches.	Weight.	Wind.	Gradient.	Uniform velocity attained.
	Tons.		One in	Miles per hour.
4	15·6	F	96	31·2
4	18·	F	96	33·72
4	18·	F	177	21·25
4	20·5	F	177	22·9
4	20·5	F	89	38·25
4	20·2	F	265	19·13
6	27·5	A	89	32·3
6	27·5	F	89	37·5
6	27·5	F	96	34·6
6	27·5	A	96	27·8
6	34·5	C	89	35·3
8	36·5	F	89	>36·5
8	40·75	F	177	26·15
8	40·75	S	177	<17·7
8	40·75	CC	89	31·4

In the third column F expresses a favourable wind, A an adverse wind, C nearly calm, CC a dead calm, and S a side wind.

The last experiment with a train of eight coaches, weighing nearly forty tons, shows that, in a dead calm, the resistance of *that train at* 31½ *miles an hour amounted to the eighty-ninth part of its weight*; *whereas the common estimate of the resistance of such a train at that speed has been hitherto about the 250th part of its weight!* This fact alone, were it unconnected with any others, would sufficiently illustrate the enormous extent of error which has prevailed hitherto in such estimations in railway practice. The third experiment with eight carriages was made with a side wind, the effect of which is abundantly manifested by the speed expressed in the last column. While the same train, moving with a fair wind down the Madeley plane, had a resistance equal to the 177th of its weight, at 26 miles an hour, its resistance with a side wind was of greater amount at 17·7 miles an hour. The relative effects of a fair and adverse wind are likewise exhibited in the third and fourth experiments with six coaches, down the Whiston plane. The velocity, which gives a resistance equal to the 96th part of the load, was 34½ miles an hour with a fair wind, and only 27⅛ with an adverse wind.

It is evident, from these experiments, that the manner in which the atmosphere resists a railway train, whatever it be, depends on the number of coaches forming the train, and that the foremost coaches do not, by clearing a passage for those which succeed them, produce any diminution of the total resistance, which is worthy of attention in practical operations.

The writer of this Report pointed out long since a probable source of resistance, which the results above stated entitle to some attention.

The wheels of the several carriages produce vortices of air around them, and play in some measure the part of fanners or blowers. A considerable force must be absorbed by so great a number of these wheels moving at such a velocity. In a train of eight carriages we have thirty-two three-feet wheels playing these parts of blowers, and revolving from four to five times in a second. How much force must be expended in maintaining such a motion, it is needless to say. But, besides this, another circumstance was observed. In these experiments, as well as in general railway practice, it is found that an extensive current of air moves beside a train, the current diminishing in velocity as the distance from the train increases. Immediately contiguous to the side of the coaches the air moves with little less velocity than the coaches themselves. Outside that is another current, moving at a less rate, and beyond that another at a further diminished rate. There is thus a succession of currents, one outside another, exending to a considerable distance at each side of the train. All the resistance produced by the lateral friction of each of these currents upon each other must be brought to the account of the aggregate resistance to the moving power; and it is evident that these resistances will depend on the length of the train and the bulk of the coaches which form it.

The following are the details of other experiments made on various gradients, with a view of illustrating the same practical principles.

July 11th, 1839.

Eight Second Class Carriages.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	40	0	0
Six Passengers	0	9	0
Gross weight .	40	9	0

Started spontaneously from a state of rest—on a curve of one mile radius—in a cutting sheltered from the wind.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
0	55	1 45 0				1000	45	1 50 0·5	16·25		12·49
100	54	46 26·5	86·5		2·36	1100	44	17	16·5		
200	53	47 7·25	40·75		5·02	1200	43	32·25	15·25		13·41
300	52	38·25	31		6·60	1300	42	47·25	15		13·63
400	51	48 4·25	26		7·86	1400	41	51 1·25	14		14·61
500	50	27·5	23·25		8·80	1500	40	15	13·75		14·87
600	49	48·75	21·25		9·62	1600	39	28·25	13·25		15·44
700	48	49 7·75	19		10·76	1700	38	41·25	13		15·73
800	47	26·5	18·75		10·91	1800	37	54·75	13·5		15·73*
900	46	44·25	17·75		11·52	1900	36	52 7·25	12·5		

Breeze down the Plane.

* Stopped by the Break.

July 11th, 1839.

Eight Second Class Carriages as before.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	40	0	0
Six Passengers	0	9	0
Gross weight .	40	9	0

Started spontaneously from a state of rest on a straight line—in a cutting sheltered from the wind.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
0	33	2 20 0				400	29	2 24 24		39	5·24
10	·9	30·5	30·5			500	28	58		34	6·01
20	·8	43·5	13			600	27	25 30		32	6·39
30	·7	53·75	10·25			700	26	26 0		30	6·81
40	·6	21 3	9·25			800	25	28·25		28·25	7·24
50	·5	11·25	8·25			900	24	55		26·75	7·64
60	·4	18·25	7			1000	23	27 20		25	8·18
70	·3	26·5	8·25			1100	22	44·25		24·25	8·43
80	·2					1200	21	28 7		22·75	8·99
90	·1	42	15·5			1300	20	29		22	9·29
100	32	49·5	7·5	109·5	1·86	1400	19	52		23	8·89*
200	31	22 55	……	65·5	3·12	1500	18	29 18·25		26·25	
300	30	23 45	……	50	4·09						

Breeze down the Plane.

* Stopped by the Break.

July 11th, 1839.

Eight Second Class Carriages as before.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	40	0	0
Six Passengers	0	9	0
Gross weight	40	9	0

Started spontaneously from a state of rest on a curve of one mile radius on embankment.

Dist.	Posts.	Times.	Diffs.	Speed.	Dist.	Posts.	Times.	Diffs.	Speed.
Yds.		h m s			Yds.		h m s		
0	15	2 38 30			1200	3	2 48 59·5	31·5	6·49
100	14	40 34	12·4	1·65	1300	2	49 31	31·5	6·49
200	13	41 40	66	3·10	1400	1	50 3	32	6·39
300	12	42 42	62	3·30	1500	0	34	31	6·60
400	11	43 37	55	3·72	1600	1	51 6	32	6·39
500	10	44 30·5	53·5	3·82	1700	2	41	35	5·84
600	9	45 23	52·5	3·90	1800	3	52 21	40	5·11
700	8	46 7	44	4·65	1900	4	53 8	47	4·35
800	7	44	37	5·53	2000	5	54 8·5	60·5	3·38
900	6	47 20	36	5·68	2100	6	55 27	78·5	2·60†
1000	5	55	35	5·84*	2183		57 54		
1100	4	48 28	33	6·20					

Train brought to rest on the Plane 1 in 267 without the Break.
Breeze down the Plane.

* End of curve. † Stopped.

July 11th, 1839.

Single Carriage, No. 12, descending on straight line. Gradient 1 in 267.

	tons.	cwts.	qrs.
Weight of Carriage and Load . . .	5	0	0
Three Passengers	0	4	2
Gross weight	5	4	2

From initial velocity 12·21 miles per hour.

Dist.	Posts.	Times.	Diffs.	Speed.	Dist .	Posts.	Times.	Diffs.	Speed.
Yds.		h m s			Yds.		h m s		
0	29	3 31 30·5			1100	40	3 36 35·5	52·5	3·90
100	30	47·25	16·75	12·21	1200	41	37 25	49·5	4·13
200	31	32 5	17·75	11·52	1300	42	38 24·5	59·5	3·43
300	32	23·25	18·25	11·21	1400	43	39 30	65·5	3·12
400	33	43	19·75	10·35	1500	44	40 49	79	2·58
500	34	33 4	21	9·74	1600	45	42 6	77	2·66
600	35	27	23	8·89	1700	46	43 45·5	99·5	
700	36	52	25	8·18	1800	47	45 29	103·5	
800	37	34 20	28	30	1900	48	50 29	300	
900	38	56	36	7·68	1974	....	54 50		*
1000	39	35 43	47	5·35					

Breeze down the Plane.

* Stopped.

July 11th, 1839.

Single Carriage, No. 9, descending on straight line. Gradient 1 in 267.

	tons.	cwts.	qrs.
Weight of Carriage and Load . . .	5	0	0
Three Passengers	0	4	2
Gross weight	5	4	2

From initial velocity 14·10 miles per hour.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	28	3 29 11				1800	46	3 34 29	22	......	9·29
100	29	27	16			1900	47	52	23		
200	30	40	13	14·5	14·10	2000	48	35 14	22	22·5	9·09
300	31	56	16			2100	49	36	22	......	9·29
400	32	30 12	16			2200	50	58	22		
500	33	27	15	......	13·05	2300	51	36 22	24	23	8·89
600	34	43	16	......	12·78	2400	52	45	23		
700	35	31 0	17			2500	53	37 11	26	24·5	8·35
800	36	17	17			2600	54	37	26	......	7·86
900	37	33	16			2700	55	38 7	30		
1000	38	51	18	17	12·03	2800	56	35	28	29	7·05
1100	39	32 8	17			2900	57	39 5	30	......	6·82
1200	40	28	20			3000	58	38	33	......	6·20
1300	41	45	17			3100	59	40 16	38	......	5·38
1400	42	33 5	20	18·5	11·05	3200	60	59	43	......	4·75
1500	43	25	20	......	10·22	3300	61	42 15	76	......	2·69
1600	44	47	22			3393	......	44 25*			
1700	45	34 7	20	21	9·74						

Breeze down the Plane.

* Stopped.

July 11th, 1839.

Four Second-Class Carriages, Nos. 5, 9, 29, 30.

	tons.	cwts.	qrs.
Weight of Carriage and Load	20	0	0
Three Passengers	0	4	2
Gross weight	20	4	2

From initial velocity 40·90 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	61	6 50 58					49	6 52 3·25	5·25	21·75	37·61
	60	51 4	6				48	9	5·75		
	59	9	5			1000	47	14·25	5·25		
	58	14	5				46	20·25	6		
0	57	19·5	5·5	21·5	38·04		45	26	5·75	22·75	35·96
	56	25	5·5				44	32·25	6·25		
	55	30·5	5·5				43	38	5·75		
	54	35·75	5·25			1500	42	44	6		
	53	41·5	5·75	22	37·18		41	50·5	6·5	24·5	33·39
500	52	47	5·5				40	56	5·5		
	51	53	6				39	53 2·25	6·25		
	50	58	5				38	8·25	6		

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
2000	37	6 53 15	6·75	24·5	33·39		15	6 59 54·25	9·25	37·25	21·96
	36	21·25	6·25				16	7 0 3	8·75		
	35	27·75	6·5				17	12·75	9·75		
	34	34·25	6·5			7500	18	22·25	9·5		
	33	……	6·5	25·75	31·77		19	32	9·75	37·75	21·67
2500	32	47·25	6·5				20	41·5	9·5		
	31	53·5	6·25				21	51·25	9·75		
	30	54 0	6·5				22	1 0·5	9·25		
	29	6·5	6·5	25·75	31·77	8000	23	10	9·5	38	21·53
	28	13	6·5				24	20	10		
3000	27	20	7				25	30·25	10·25		
	26	27	7				26	40·25	10		
	25	34·25	7·25	27·75	29·48		27	50·25	10	40·25	20·32
	24	41·25	7			8500	28	2 0	9·75		
	23	48·75	7·5				29	10	10		
3500	22	55·75	7				30	20	10		
	21	55 3	7·25	28·75	28·45		31	30·25	10·25	40	20·45
	20	10	7				32	40·25	10		
	19	17	7			9000	33	50·25	10		
	18	25	8				34	3 0·5	10·25		
4000	17	32·5	7·5	29·5	27·73		35	10·5	10		
	16	39·75	7·25				36	21	10·5	50·75	19·80
	15	47·5	7·75				37	31	10		
	14	55	7·5			9500	38	41·25	10·25		
	13	56 2	7	29·5	27·73		39	52	10·75		
4500	12	9·75	7·75				40	4 2·5	10·5	41·5	19·71
	11	17·25	7·5				41	13	10·5		
	10	25	7·75				42	23·75	10·75		
	9	32·75	7·75	30·75	26·61	10,000	43	34·25	10·5		
	8	40	7·25				44	44·75	10·5	42·25	19·36
5000	7	48	8				45	55·5	10·75		
	6	55·75	7·75				46	5 6	10·5		
	5	57 3·25	7·5	30·5	26·82		47	16·25	10·25		
	4	11·25	8			10,500	48	27·5	11·25	42·75	19·13
	3	19·25	8				49	38	10·5		
5500	2	27·25	8				50	49	11		
	1	35·25	8	32	25·57		51	6 0	11		
	0	43·5	8·25				52	10·25	10·25	42·75	19·13
	1	51·5	8			11,000	53	21	10·75		
	2	58 0	8·5				54	32·5	11·5		
6000	3	7·75	7·75	32·5	25·17		55	43	10·5		
	4	16	8·25				56	54	11	43·75	18·70
	5	24·5	8·5				57	7 4·5	10·5		
	6	33·25	8·75			11,500	58	15·5	11		
	7	42	8·75	34·25	23·89		59	27	11·5		
6500	8	50·75	8·75				60	38·5	11·5	44·5	18·38
	9	59 0	9·25				61	50	11·5		
	10	8·5	8·5				62	8 1·25	11·25		
	11	17	8·5	35	23·37	12,000	63	13	11·75		
	12	26·5	9·5				64	25	12	46·5	17·58
7000	13	37·55	9·25				65	37	12		
	14	45	9·25				66	47·75	11·75		

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	67	7 9 1	12·25			.	75	....	13·25		
12,500	68	13·25	12·25	48·25	16·95		76	7 10 57·25	13·5	53·25	15·36
	69	25·75	12·5				77	11 11	13·75		
	70	38·5	12·75			13,500	78	24·5	13·5		
	71	51·75	13·25			13,785	...	12 8			
	72	10 4	12·25	50·75	16·12	13,915	...	32·25			
13,000	73	17	13			14,242	...	13 59·5			
	74	30·5	13·5			14,498	...	14 45·5 *			

A Stiff Breeze down the Plane.

* Stopped.

July 11th, 1839.

Four Second Class Carriages, Nos. 12, 20, 35, 22.

	tons.	cwts.	qrs.
Weight of Carriage and Load	20	0	0
Seven Passengers		10	2
	20	10	2

From initial velocity 32·73 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	61	7 11 4					34	7 14 3	7		
	60	11	7				33	10	7	29	28·21
	59	16	5			2500	32	18	8		
	58	23	7				31	26	8		
0	57	29	6	25	32·73		30	33	7		
	56	35	6				29	40	7	30	27·27
	55	41	6				28	48	8		
	54	48	7			3000	27	56	8		
	53	54	6	25	32·73		26	15 4	8		
500	52	12 1	7				25	11	7	31	26·39
	51	8	7				24	20	9		
	50	14	6				23	28	8		
	49	21	7	27	30·30	3500	22	36	8		
	48	26	5				21	44	8	33	24·79
1000	47	33	7				20	52	8		
	46	40	7				19	16 0	8		
	45	47	7	26	31·46		18	8	8		
	44	53	6			4000	17	...	9	33	24·79
	43	13 0	7				16	26	9		
1500	42	7	7				15	35	9		
	41	14	7	27	30·30		14	44	9		
	40	21	7				13	53	9	36	22·72
	39	28	7			4500	12	17 2	9		
	38	34	6				11	11	9		
2000	37	41	7	27	30·30		10	18	7		
	36	48	7				9	28	10	35	23·37
	35	56	8								

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	8	7 17 36	8				31	7 24 37	13	52	15·73
5000	7	45	9				32	50	13		
	6	54	9			9000	33	25 3	13		
	5	18 3	9	35	23·37		34	16	13		
	4	13	10				35	29	13		
	3	22	9				36	43	14	66	12·39
5500	2	31	9				37	57	14		
	1	40	9	37	22·11	9500	38	26 11	14		
	0	49	9				39	25	14		
	1	58	9				40	40	15	57	14·35
	2	19 7	9				41	55	15		
6000	3	17	10	37	22·11		42	27 10	15		
	4	27	10			10,000	43	25	15		
	5	37	10				44	40	15	60	16·63
	6	47	10				45	55	15		
	7	57	10	40	20·44		46	28 10	15		
6500	8	20 7	10				47	27	17		
	9	17	10			10,500	48	44	17	64	12·79
	10	27	10				49	29 1	17		
	11	38	11	41	19·95		50	18	17		
	12	50	12				51	36	18		
7000	13	21 1	11				52	53	17	69	11·85
	14	12	11			11,000	53	30 10	17		
	15	23	11	45	18·18		54	28	18		
	16	34	11				55	48	20		
	17	44	10				56	31 8	20	75	10·91
7500	18	56	12				57	28	20		
	19	22 8	12	45	18·18	11,500	58	50	22		9·29
	20	20	12				59	32 13	23		
	21	32	12				60	36	23		8·89
	22	44	12				61	33 2	26		
8000	23	56	12	48	17·04		62	27	25	25·5	8·02
	24	23 8	12			12,000	63	55	28		7·30
	25	21	13				64	34 28	33		6·20
	26	33	12				65	35 2	34		6·01
	27	45	12	49	16·69		66	38	36		5·68
8500	28	58	13				67	36 23	45		4·54
	29	24 11	13			12,500	68	37 30	67		3·05
	30	24	13			12,555		39 8			*

A Stiff Breeze down the Plane.

* Stopped at 68 post + 55 yards.

July 12th, 1839.

Six Second Class Carriages, Nos. 35, 9, 29, 22, 12, 20.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	30	0	0
Six Passengers	0	9	0
Gross weight . . .	30	9	0

From initial velocity 25·57 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.	Dist.	Posts.	Times.			Diffs.		Speed.
Yds.		h	m	s				Yds.		h	m	s			
	61	1	36	53·5					19	1	43	19·5	11·5		
	60		37	2	8·5				18			32	12·5		
	59			10	8			4000	17			44·5	12·5	48	17·04
	58			18·5	8·5				16			56	11·5		
0	57			26	7·5	32·5	25·17		15		44	8·5	12·5		
	56			34	8				14			21	12·5		
	55			42	8				13			33·5	12·5	49	16·69
	54			50	8			4500	12			46·25	12·75		
	53			58	8	32	25·57		11			58·75	12·5		
500	52		38	6	8				10		45	11·75	13		
	51			……	8·5				9			25	13·25	51·5	15·88
	50			23	8·5				8			38	13		
	49			……	8	33	24·79	5000	7			52·5	14·5		
	48			39	8				6		46	6	13·5		
1000	47			48·25	9·25				5			20·75	14·75	55·75	14·67
	46			56·5	8·25				4			36	15·25		
	45		39	5·25	8·75	34·25	23·89		3			50·75	14·75		
	44			14	8·75			5500	2		47	4·75	14		
	43			23	9				1			19·5	14·75	58·75	13·92
1500	42			31·5	8·5				0			34	14·5		
	41			40·25	8·75	35	23·37		1			48·5	14·5		
	40			48·5	8·25				2		48	3	14·5		
	39			58·5	10			6000	3			19·25	16·25	59·75	13·69
	38		40	7·75	9·25				4			35	15·75		
2000	37			16·5	8·75	36·25	22·57		5			52	17		
	36			25·75	9·25				6		49	9	17		
	35			35	9·25				7			27·5	18·5	68·25	11·98
	34			44·25	9·25			6500	8			48	20·5		
	33			53·5	9·25	37	22·11		9		50	9	21		
2500	32		41	2·5	9				10			30·5	21·5		
	31			11·25	8·75				11			53	22·5	85·5	9·56
	30			21	9·75				12		51	14·75	21·75		
	29			30·5	9·5	37	22·11	7000	13			39	24·25		
	28			40·25	9·75				14		52	2·5	23·5		
3000	27			50·25	10				15			27·25	24·75	94·25	8·64
	26		42	0·5	10·25				16			53·5	26·25		7·79
	25			11·25	10·75	40·75	20·07		17		53	22·5	29		7·05
	24			22·25	11			7500	18			56·5	34		6·01
	23			33·5	11·25				19		54	37·25	40·75		5·02*
3500	22			45	11·5				20		55	25·5	48·25		
	21			56·5	11·5	45·25	18·08	7800	21		56	31·25	65·75		
	20		43	8	11·5			7881			58	33·5			

* Stopped at 21 post + 81 yards.

Breeze from the west, or nearly at right angles to road.

July 12th, 1839.

Eight Second Class Carriages.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	40	0	0
Six Passengers	0	9	0
Gross weight . . .	40	9	0

From initial velocity 20·07 miles per hour, down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yds.		h	m	s			
	61	2	30	58			
	60		31	14	16	....	12·78
	59			27	13	....	15·73
	58			38	11	....	18·59
0	57			48·75	10·75	....	19·02
	56			59	10·25		
	55		32	9	10		
	54			19·25	10·25		
	53			29·5	10·25	40·75	20·07
500	52			40	10·5		
	51			50	10		
	50		33	0	10		
	49			9	9	39·5	20·71
	48			19	10		
1000	47			29·25	10·25		
	46			39	9·75		
	45			49·25	10·25	40·25	20·33
	44			58·5	9·25		
	43		34	8·5	10		
1500	42			18	9·5		
	41			27·75	9·75	38·5	21·25
	40			37·5	9·75		
	39			47·25	9·75		
	38			56·25	9		
2000	37		35	5·5	9·25	37·75	21·67
	36			15·5	10		
	35			25	9·5		
	34			35	10		
	33			44·75	9·75	39·25	20·84
2500	32			54·25	9·5		
	31		36	3·5	9·25		
	30			13·25	9·75		
	29			23	9·75	38·25	21·39
	28			32·75	9·75		
3000	27			42·75	10		
	26			53	10·25		
	25		37	2·5	9·5	39·5	20·71
	24			12·5	10		
	23			22·5	10		
3500	22			33·5	11		
	21			44·25	10·75	41·75	19·59
	20			54·5	10·25		
	19		38	5·25	10·75		
	18	2	38	16·25	11		
4000	17			27·25	11	43	19·02
	16			38	10·75		
	15			49·75	11·75		
	14		39	0	10·25		
	13			11	11	43·75	18·70
4500	12			22	11		
	11			33	11		
	10			44·25	11·25		
	9			55·0	10·75	44	18·59
	8		40	6	11		
5000	7			17·5	11·5		
	6			29·25	11·75		
	5			41	11·75	46	17·78
	4			52·75	11·75		
	3		41	4	11·25		
5500	2			......	11·5		
	1			27·25	11·75	46·25	17·69
	0			39	11·75		
	1			50·5	11·5		
	2		42	1·5	11		
6000	3			13·25	11·75	46	17·78
	4			25·75	12·5		
	5			37·75	12		
	6			50·25	12·5		
	7		43	3·25	13	50	16·36
6500	8			16·25	13		
	9			29·5	13·25		
	10			43·5	14		
	11			57	13·5	53·75	15·22
	12		44	10·25	13·25		
7000	13			24·5	14·25		
	14			39	14·5		
	15			53·25	14·25	56·25	14·54
	16		45	7	13·75		
	17			22	15		
7500	18			37	15		
	19			53	16	59·75	13·69
	20		46	8	15		
	21			23·75	15·75		
	22			39·75	16		
8000	23			56	16·25	63	12·98

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	24	2 47 13	17				40	2 52 50·75	26·75		
	25	30·5	17·5				41	53 15·5	24·75		
	26	48·5	18				42	43	27·5		
	27	48 6	17·5	70	11·69	10,000	43	54 7·75	24·75	103·75	
8500	28	24 25	18·25				44	35	27·25		
	29	43 25	19				45	55 3	28		
	30	49 2·5	19·25				46	32·5	29·5		
	31	22·25	19·75	76·25	10·73		47	56 3	30·5		
	32	42·5	20·25			10,500	48	35·75	32·75		
9000	33	50 3·5	21				49	57 8	32·25		
	34	26	22·5				50	42·5	34·5		
	35	48·5	22·5	86·25	9·48		51	58 21	38·5		
	36	51 11	22·5				52	59 2	41		
	37	34·75	23·75			11,000	53	53	51		
9500	38	58·5	23·75			11,100	54	3 1 15	82		
	39	52 24	25·5	95·5		11,154	......	2 42·5	*		

Wind from west, but rather less than in preceding.

* Stopped at 42 + 37 yards; the last 600 or 800 yards were in a cutting completely sheltered from the wind.

July 12th, 1839.

Experiments continued on Sutton Inclined Sutton Plane.

Four Second Class Carriages, Nos. 30, 5, 20, 12.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	20	0	0
Six Passengers	0	9	0
Gross weight	20	9	0

From initial velocity 33·64 miles per hour, down Sutton Incline.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yds.		h m s				Yds.		h m s			
	4	6 20 53·5				1210	11	6 22 30	6·25		
	3		6			1320	12	36	6	24·75	36·36
	2	21 6	6·5			1430	13	42·25	6·25		
	1	12·5	6·5			1540	14	48·25	6		
0	0	19·25	6·75	25·75	34·95	1650	15	54·75	6·5		
110	1	26·25	7			1760	16	23 0·5	5·75	24·5	36·73
220	2	32·75	6·5			1870	17	6	5·5		
330	3	39·25	6·5			1980	18	12·25	6·25		
440	4	46	6·75	26·75	33·64	2090	19	18	5·75		
550	5	52·5	6·5			2200	20	24	6	23·5.	38·29
660	6	58·5	6			2310	21	30·25	6·25		
770	7	22 5	6·5			2420	22	36	5·75	6	37·50
880	8	11·25	6·25	25·25	35·64	2530	23	42·5	6·5		
990	9	17·25	6			2640	24	49	6·5		
1100	10	23·75	6·5								

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yds.		h m s				Yds.		h m s			
2750	25	6	6·5	6·5	34·61	4180	38	6 25 4·5	10·5		21·43
2860	26	24 2.5	7			4290	39	55·75	10·75		
2970	27	9	6·5	6·75	33·33	4460	40	26 6·25	10·5	10·62	21·17
3080	28	16·75	7·75			4510	41	18·25	12	......	18·75
3190	29	24·5	7·75			4620	42	31·25	13	......	17·30
3300	30	32·25	7·75	7·75	29·03	4730	43	45	13·75	......	16·36
3410	31	40	7·75			4840	44	59·5	14·5	......	15·51
3520	32	48·25	8·25	8	28·12	4950	45	27 15·25	15·75	......	14·28
3630	33	57	8·75			5060	46	33	17·75	......	12·67
3740	34	25 5·75	8·75	8·75	25·71	5170	47	52	19	......	11·84
3850	35	15	9·25			5203	xiii $\frac{\text{I}}{\text{IV}}$	58			
3960	36	24·25	9·25	9·25	24·32	5643	xiii $\frac{\text{I}}{\text{II}}$	29 40	*		
4070	37	34·5	10·25	.....	21·95	5869		32 0			

A light breeze from west, or down the Plane.

* Stopped at xiii $\frac{\text{I}}{\text{II}}$ mile post, + 226 yards.

July 12th, 1839.

Six Second Class Carriages, Nos. 30, 5, 20, 12, 22, 29.

	tons.	cwts.	qrs.
Weight of Carriages and Load .	30	0	0
Six Passengers	0	9	0
Gross weight . .	30	9	0

From initial velocity 26·47 miles per hour, down Sutton Incline.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	4	7 23 31				2090	19	7 26 20·75	6·75		
	3	38·5	7·5			2200	20	27·25	6·5	25·5	35·29
	2	46·75	8·25			2310	21	34	6·75		
	1	55	8·25			2420	22	40	6	6·38	35·29
0	0	24 3·5	8·5	32·5	27·69	2530	23	47	7		
110	1	12·25	8·75			2640	24	54	7		
220	2	20	7.75			2750	25	27 0·5	6·5	6·83	32·92
330	3	28·25	8·25			2860	26	7·5	7	......	32·14
440	4	36	7·75	32·5	27·69	2970	27	15	7·5	......	30·00
550	5	44	8			3080	28	23	8		
660	6	51·5	7·5			3190	29	31	8		
770	7	59	7·5			3300	30	39	8	8	28·12
880	8	25 6	7	30	30·00	3410	31	47	8	......	28·12
990	9	13	7			3520	32	55·5	8·5	......	26·47
1100	10	20·25	7·25			3630	33	28 4·75	9·25		
1210	11	27·5	7·25			3740	34	14	9·25		
1320	12	34·5	7	28·5	31·58	3850	35	23·25	9·25	9·25	24·32
1430	13	41·25	6·75			3960	36	33·5	10·25		
1540	14	48·25	7			4070	37	43·75	10·25	10·25	21·95
1650	15	55	6·75			4180	38	54·5	10·75	......	20·93
1760	16	26 1·75	6·75	27·25	33·02	4290	39	29 5·5	11	......	20·45
1870	17	8	6·25								
1980	18	14	6								

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yds.		h m s				Yds.		h m s			
4400	40	7 29 17·5	12	......	18·75	4950	45	7 30 29·25	17	......	13·23
4510	41	30	12·5	......	18·00	5060	46	48	18·75	......	12·00
4620	42	43·25	13·25	......	16·98	5170	47	31 8	20	......	11·25*
4730	43	57·25	14	......	16·07	5203	XIII $\frac{I}{IV}$	14			
4840	44	30 12·25	15	......	15·00	5616		34 3			

Nearly calm.

* Stopped at XIII $\frac{I}{IV}$ mile post + 413 yards.

July 12th, 1839.

Eight Second Class Carriages.

	tons.	cwts.	qrs.
Weight of Carriages and Load .	40	0	0
Six Passengers	0	9	0
Gross weight .	40	9	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	7 52 0				3080	28	7 57 22	9		
110	1	55	55	......	4·09	3190	29	30·5	8·5	8·75	25·71
220	2	53 17	22	......	10·22	3300	30	39·25	8·75		
330	3	35	18	......	12·50	3410	31	49	9·75	9·25	24·32
440	4	50	15	......	15·00	3520	32	58	9		
550	5	54 3·5	13·5	......	16·66	3630	33	58 8	10		
660	6	16	12·5	......	18·00	3740	34	18	10	9·66	23·27
770	7	27·25	11·25	......	20·00	3850	35	29	11		
880	8	38	10·75	......	20·93	3960	36	40	11	11	20·45
990	9	48·25	10·25	......	21·95	4070	37	51·75	11·75		
1100	10	58·25	10	......	22·50	4180	38	59 3·5	11·75	11·75	19·15
1210	11	55 7·75	9·5	......	23·68	4290	39	16	12·5	......	18·00
1320	12	16·5	8·75	......	25·71	4400	40	29	13	......	17·30
1430	13	25	8·5	......	26·47	4510	41	43·25	14·25	......	15·79
1540	14	34	9			4620	42	58	14·75	......	15·25
1650	15	41·75	7·75	8·37	26·86	4730	43	8 0 14	16	......	14·06
1760	16	50	8·25	......	27·27	4840	44	31·75	17·75	......	12·67
1870	17	57·75	7·75	......	29·03	4950	45	51·5	19·75	......	11·39
1980	18	56 5	7·25			5060	46	1 13	21·5	......	10·46
2090	19	12·75	7·75	7·5	30·00	5170	47	38·5	25·5	......	8·82*
2200	20	19·75	7			5203	XIII $\frac{I}{IV}$	47			
2310	21	27·5	7·75			5485		4 19			
2420	22	34·25	6·75	7·17	31·39						
2530	23	41·75	7·5								
2640	24	49·5	7·75	7·67	29·51						
2750	25	57	7·5								
2860	26	57 4·5	7·5								
2970	27	13	8·5	7·83	28·72						

Dead calm.

* Stopped at XIII $\frac{I}{IV}$ mile post + 282 yards.

Google

SUMMARY OF THE PRINCIPAL RESULTS OBTAINED IN THE EXPERIMENTS

DOWN MADELEY PLANE.

No. of Experiments.	Description of Train.	Weight.		Initial velocity.	Uniform velocities on planes.				Dist. passed over from 57 post.	State of Wind.	Observations.
					$\frac{1}{177}$	$\frac{1}{263}$	$\frac{1}{330}$	Level.			
		t. c. q.		Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Yards.		
1	Eight Carriages	40 15 0	Projected on to $\frac{1}{177}$ plane	23·71	24·21	19·81	Retar.	Stopd.	14411	Breeze down plane	Beak or pointed end attached in front.
2	Ditto	40 15 0	ditto	23·37	26·83	19·63	Retar.	Stopd.	14331	ditto	Beak removed on $\frac{1}{177}$ plane, first accel. and then retard.
3	Ditto	40 15 0	ditto	26·39	25·57	Retar.	Retar.	Stopd.	13967	ditto	Retarded on $\frac{1}{263}$ plane to 18·08 miles per h. spaces closed up.
12	Ditto	40 9 0	ditto	20·07	Accel. & retar.	....	....	....	11154	Side wind........	Stopped on $\frac{1}{263}$ plane in calm.
6	Ditto	40 9 0	Projected on to $\frac{1}{263}$ plane	6·60	Retar. & stop.	....	....	....	....	Breezedown plane	Run 683 yards and stopped.
6	Ditto	40 9 0	From rest on $\frac{1}{177}$ (curve)	0	Accelerated...	Stopd.	....	....	....	ditto	Run a per preceding.
4	Ditto	40 9 0	ditto	0	ditto	....	....	....	....	Sheltered	Stopped by break.
5	Ditto	40 9 0	ditto, (straight)	0	ditto	....	....	....	....	ditto	ditto
11	Six Carriages	30 9 0	Projected on to $\frac{1}{177}$ plane	25·57	Retarded	Stopd.	....	....	7881	Side wind	Retarded on $\frac{1}{177}$ plane to 13·92.
9	Four Carriages	20 4 2	ditto	40·90	ditto	19·13	Retar.	Stopd.	14498	Stiff breeze down plane	ditto to 25·57.
10	Ditto	20 10 2	ditto	32·73.	ditto	Retar.	Stopd.	....	12555	ditto	ditto to 23·37.
7	One Carriage, No. 12	5 4 2	Projected on to $\frac{1}{263}$ plane	12·21	....	Stopd.	....	....	....	Breezedown plane	Ran 1974 yards and stopped.
8	One ditto, No. 6	5 4 2	ditto..................	14·10	....	Stopd.	....	....	....	ditto	Ran 3393 yards and stopped.

DOWN SUTTON PLANE.

13. Four Carriages 20 tons 9 cwts. projected on to $\frac{1}{89}$ plane, at 33·33 miles per hour, accelerated to 38·29. Breeze down the plane. Ran 5869 yards.
14. Six ditto 30 9 ditto at 26·47 miles per hour, accelerated to 35·29. Nearly calm. Ran 5616 yards.
15. Eight ditto 40 9 From rest at No. 0 post. Accelerated to 31·29. Dead calm. Ran 5485 yards.

The obvious tendency which this body of experiments had to support, a principle—which the author of this Report had advanced and supported before a Committee of the House of Lords in the year 1835, but which then and ever since was declared by engineers to be paradoxical and absurd, and one which had no foundation in practice—suggested the trial of one extended experiment, by which the truth or falsehood of that doctrine would be put beyond all doubt. The doctrine referred to was, *that a railway laid down with gradients not exceeding twenty feet a mile would be for all practical purposes, nearly if not altogether as good as a railway of equal length laid down from terminus to terminus on a dead level.* The grounds on which he advanced this doctrine were, that a compensation would be obtained on the descending gradients for the disadvantages of the ascending gradients. This compensation would be either in TIME, or POWER, or BOTH, which would be saved in the descent; and he consequently maintained, that a railway graduated within the limits proposed would be worked at as great an average speed, and with as small an expenditure of moving power, as a dead level*.

If the principle now advanced be admitted, it will follow that the whole amount of inconvenience which would ensue from the adoption of eighteen or twenty-foot gradients would be a variation in the speed of transport. The *average* speed, the time of completing the journey, the expenditure of power, the expense of maintaining the line, and supplying it with locomotive power, would be the same. The great practical importance of these circumstances is quite evident.

To reduce this question to the immediate test of experiment, it was determined to prepare an engine and full train of twelve coaches loaded as such a train would be in the ordinary traffic of a railway, and to run this train on the railway from Liverpool to Birmingham and back, observing the moment of passing each quarter-mile post, and obtaining thereby the actual speed with which each gradient, from one end to the other of the line, was ascended and descended, and the speed on the levels. By taking a mean of the speed in ascending and descending the gradients, it would be necessary, if the principle maintained by the writer of this Report were valid, that this mean should be exactly or very nearly equal to the speed on the level.

The experiment was accordingly made on the 16th July 1839, and the following are the details of it:—

Experiment with the Hecla Locomotive Engine.

On a trip from Liverpool to Birmingham and back, with a load consisting of the Tender and Twelve Second Class Grand Junction Carriages.

Weather fine and calm; rails dry; water in the tender warm.

	tons.	cwt.	qrs.	tons.	cwt.	qrs.
Hecla Engine .				12	0	0
Tender	10	0	0			
Carriages, No. 5,	5	0	0			
Do. 30,	5	0	0	20	0	0
Carried forward				32	0	0

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* The principle here advocated has nothing in common with that of the *undulating railway* proposed some years ago. That project had for its foundation a supposed advantage, derivable from the acceleration of the load descending inclined planes of *greater inclination than the angle of repose*; it was maintained, that the momentum thus acquired would compensate for the steepness of the plane in the ascent, and it was essential to this project that the gradients *should exceed the angle of repose.* It is, on the contrary, essential to the principle maintained in the present Report, that the gradients *should* NOT exceed the angle of repose. The principle of what was called the *undulating railway* was evidently fallacious.

	tons.	cwt.	qrs.	tons.	cwt.	qrs.
Brought forward				32	0	0
Carriages, No. 29,	5	0	0			
Do. 9,	5	0	0			
Do. 12,	5	0	0			
Do. 20,	5	0	0			
Do. 22,	5	0	0			
Do. 35,	5	0	0			
Do. 31,	5	0	0			
Do. 5,	5	0	0			
Do. 23,	5	0	0			
Do. (open) 7,	5	0	0	50	0	0
Gross weight of Train . . .				82	0	0

Dimensions of the Hecla.

	ft.	in.
Diameter of Driving Wheels	5	0
Diameter of Cylinder	0	12½
Length of Stroke	0	18
Diameter of Blast-pipe	0	2⅞

Internal Dimensions of Firebox.

Width crosswise	3	6⅙
Length lengthwise	2	4¼
Depth from underside of roof to top of Grate Bars	3	4½
Number of Tubes 117.		
Length of Tubes	8	6½
External diameter	0	1⅜

Heating surface per lineal foot . . .	·375	sq. feet.
Heating surface of Firebox	45·38	do.
Heating surface of Tubes	373·7	do.
Total heating surface . .	419·08	do.

"Hecla," Tender and Twelve Carriages.

From Liverpool to Birmingham.

Gradient.	Mileposts.	Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.
		h m s				
Fall $\frac{1}{1094}$	12	10 28 12				
	3	29 33	81	......	11·11	
	2	30 25	52	......	17·30	
	2	31 46	81	......	22·22	
	3	32 23	37	......	24·32	
	3	57	34	......	26·47	
	1	33 28	31	......	29·03	
	2	58	30	......	30·00	
	3	34 26	28	......	32·14	
	4	53	27	......	33·33	
	1	35 20	27	......	33·33	
		h m s				
Fall $\frac{1}{1094}$	2	10 35 46	26	26·00	34·61	
	3	36 12	26			
	5	38	26			
	1	37 3	25			
	2	29	26			
	3	55	26			
	6	38 21	26			
	1	47	26			
	2	39 14	27			
	3	39	25			
	7	40 6	27			

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Rise $\frac{1}{96}$	1	10	40	37	31	......	29·03	
	2		41	13	36	......	25·00	
	3			55	42	......	21·43	
	8		42	45	50	......	18·00	
	1		43	43	58	......	15·56	
Level	2		44	49	66	......	13·63	
	3		45	38	49	......	18·37	
	9		46	16	38	......	23·68	
	1			50	34	......	26·47	
	2		47	23	33	......	27·27	
	3			53	30	30·0	30·00	
	10		48	24	31			
	1			54	30			
Fall $\frac{1}{89}$	2		49	25	31			
	3			53	28			
	11		50	20	27	......	33·33	
	1			48	28	......	32·14	Slacknd.
Fall $\frac{1}{2762}$	13		55	47	4·59	......	21·07	do. Having overtaken 2nd Class L. & M. Train.
	2		57	17	1·30	......	20·00	do.
	3			58	41	......	21·95	do.
	14		58	35	37	......	24·32	do.
	1		59	13	38	......	23·68	do.
Avg^e Fall $\frac{1}{314}$	2			56	43	......	20·93	do.
	19	11	9	26	9·30	......	28·42	
	1			54	28	......	32·14	
			10	30	......	......	......	Stopd. Warrington.
Rise $\frac{1}{308}$	½		43	4	......	......	......	Start.
	3		44	34				
	20		45	35	61	......	14·75	
	1		46	25	50	......	18·00	
Rise $\frac{1}{3474}$	½ 3		47	48	83	......	21·68	
	21		48	25	37	......	24·32	
	1			58	33	......	27·27	
	3		50	2	64	......	28·12	
	22·1		51	1	59	......	30·51	
	2			30	29	......	31·03	
	3							
	23		52	27	57	......	31·58	
Rise $\frac{1}{310}$	1			56	29	......	31·03	
	2		53	27	31	......	29·03	
	3			58	31	......	29·03	
	24		54	30	32	......	28·12	
	24·2		55	35	65	......	27·70	
Rise $\frac{1}{100}$	3		56	8	33	......	27·27	
	25			45	37	......	24·32	
Rise $\frac{1}{180}$	1		57	27	42	......	21·43	
	2		58	11	44	......	20·45	
	3			54	43	......	20·93	
	26		59	38	44	......	20·45	
Level.	1	12	0	20	42	......	21·43	
Fall $\frac{1}{338}$	2			55	35	......	25·71	
	3		1	27	32	......	28·12	
	27			56	29	......	31·03	
	1		2	25	29	......	31·03	
	2		2	51	26	......	34·61	
Level.	3		3	18	27	......	33·33	
Rise $\frac{1}{330}$	28			45	27	......	33·33	
	1		4	15	30	......	30·00	
Rise $\frac{1}{350}$	2	12	4	44	29	......	31·03	
	3		5	13	29	......	31·03	
	29			48	35	......	25·71	
	1		6	22	34	......	26·47	
Level	2			55	33	......	27·27	
	3		7	27	32	......	28·12	
	30			58	31	......	29·03	
Rise $\frac{1}{440}$	1		8	28	30	......	30·00	
	2			58	30	......	30·00	
	3		9	28	30	......	30·00	
	31		10	0	32	......	28·12	
Rise $\frac{1}{1383}$	1			32	32	......	28·12	
	2		11	3	31	......	29·03	
	3			41	38	......	23·68	
			12	47	...	......	......	Stop. Hartford.
			16	20	...	......	......	Start.
Fall $\frac{1}{350}$	32			53				
	1		17	53	60	......	15·00	
	2	12	18	32	39	......	23·07	
	3		19	6	34	......	26·47	
Level	33			37	31	......	29·03	
	1		20	7	30	......	30·00	
Rise $\frac{1}{400}$	2			37	30	......	30·00	
	3		21	10	33	31	29·03	
	34			39	29			
	1		22	12	33	33	27·27	
	2			45	33			
	3		23	19	34			
	35			51	32			
	1		24	24	33			
Rise $\frac{1}{2200}$	2			55	31	......	29·03	
	3		25	26	31	......	29·03	
	36			55	29	......	31·03	
	1		26	25	30	......	30·00	
Rise $\frac{1}{330}$	2			55	30	......	30·00	
	3		27	27	32	......	28·12	
	37		28	0	33	......	27·27	
	1			33	33	......	27·27	
Level	2		29	7	34	......	26·47	
	3			40	33	......	27·27	
	38		30	12	32	......	28·12	
Rise $\frac{1}{440}$	1			43	31	......	29·03	
	2		31	14	31	......	29·03	
	3			43	29	30·5	29·50	
	39		32	15	32			
	1			47	32	......	28·12	
	2		33	19	32	......	28·12	
Level	3			52	33	......	27·27	
	40		34	22	30	......	30·00	
	1			52	30	30	30·00	
	2		35	22	30			
	3			52	30			
	41		36	21	29	29·3	30·71	
	1			50	29			
	2		37	20	30			
	3			50	30			
	42		38	19	29			
	1			49	30			

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.	Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s							h	m	s				
	2	12	39	18	29					3	1	21	20	26	......	34·61	
	3			47	29					57			46	26	......	34·61	
	43		40	16	29	29·3	30·71			1		22	13	27			
Level	1			45	29				Fall	2			40	27			
			42	0				Stop.		3		23	7	27			
			47	30				Start. Crewe.	$\frac{1}{390}$	58			35	28	27·14	33·16	
	3		48	12						1		24	2	27			
	44		49	18	66	......	13·63			2			30	28			
	1		50	8	50	......	18·00			3			56	26			
Rise	2			54	46	......	19·56			59		25	23	27			
$\frac{1}{330}$	3		51	35	41	......	21·95			1			49	26			
	45		52	15	40	......	22·50			2		26	17	28			
	1			58	38	......	23·68		Fall	3			43	26			
	2		53	30	37	......	24·32		$\frac{1}{650}$	60		27	11	28	27·62	32·58	
	3		54	6	36					1			38	27			
	46			42	36					2		28	8	30			
	1		55	18	36					3			37	29			
	2			51	33					61		29	5	28			
Rise	3		56	31	40					1			33	28			
$\frac{1}{263}$	47		57	8	37	36·18	24·87			2		30	2	29			
	1			46	38					3			30	28			
	2		58	22	36					62			59	29			Sm. low.
	3			58	36					1		31	27	28			Bd.coke.
	48		59	33	35					2			55	28			
	1	1	0	8	35					3		32	23	28			
	2			45	37					63			51	28			
	3		1	21	36	36·5	24·66		Fall	1		33	19	28			
	49			59	38	......	23·68			2			47	28	28·70	31·36	
	1		2	37	38	......	23·68		$\frac{1}{303}$	3		34	16	29			
	2		3	17	40					64			44	28			
Rise	3			57	40					1		35	14	30			
$\frac{1}{177}$	50		4	38	41					2			43	29			
	1		5	20	42					3		36	13	30			
	2		6	0	40	40·44	22·25			65			42	29			
	3			40	40					1		37	12	30			
	51		7	20	40					2			41	29			
	1		8	1	41					3		38	11	30			
	2			41	40					66			40	29	......	31·03	
	3		9	22	41	......	21·95			1		39	12	32	......	28·12	
	52		10	0	38	......	23·68			2			45	33	......	27·27	
Rise	1			37	37	......	24·32		Fall	3		40	18	33	......	27·27	
$\frac{1}{330}$	2		11	14	37	......	24·32		$\frac{1}{2103}$	67			53	35	......	25·71	
	3			49	35	......	25·71			2		42	7	1·14	......	24·32	
	53		12	24	35	......	25·71			3			42	35	......	25·71	
	1			58	34	......	26·47			68		43	21	39	......	23·07	
Level	2		13	32	34	......	26·47					44	30		......	......	Stopped.
	3		14	7	35	......	25·71	Slackd.				51	5		......	......	Started.
	54		15	1	54	......	16·66	do.		2		52	31				
	1			48	47	......	19·15	do. Whitmore.	Rise	3		53	27	56	......	16·07	
	2		16	52	64	......	14·06	do.	$\frac{1}{636}$	69		54	16	49	......	18·37	
	3		17	30	38	......	23·68			1			58	42	......	21·43	
Fall	55		18	5	35	......	25·71			2		55	36	38	......	23·68	
$\frac{1}{390}$	1			36	31	......	29·03			3		56	15	39	......	23·07	
	2		19	6	30	......	30·00		Level	70			50	35	......	25·71	
	3			33	27					1		57	23	33	......	27·27	
	56		20	1	28	27	33·33			2			54	31	......	29·03	
	1			27	26				Rise	3		58	27	33	......	27·27	
	2			54	27				$\frac{1}{400}$	71		59	0	33	......	27·27	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h.	m.	s.				
Rise $\frac{1}{400}$	1	1	59	34	34	34	26·47	
	2	2	0	8	34			
	3			41	33			
	72		1	15	34			
	1			50	35			
	2		2	23	33	33·5	26·87	
Level	3			57	34			
	73·1		4	1	64	......	28·12	
	2			30	29	......	31·03	
	3		5	0	30	......	30·00	
Rise $\frac{1}{440}$	74			30	30	......	30·00	
	1		6	2	32	......	28·12	
	2			36	34	32·5	27·70	
	3		7	7	31			
	75		7	39	32	......	28·12	
	1		8	12	33	......	27·27	
	2			45	33	......	27·27	
	3		9	20	35	......	25·71	
Rise $\frac{1}{330}$	76			55	35	......	25·71	
	1		10	30	35	35·36	25·45	
	2		11	5	35			
	3			38	33			
	77		12	12	34			
	1			47	35			
	2		13	22	35			
	3			57	35			
	78		14	31	34			
	1		15	8	37			
	2			43	35			
	3		16	21	38			
	79			57	36			
	1		17	34	37			
	2		18	11	37			
	3			47	36			
	80		19	23	36			
	1		20	0	37			
	2							
	3		21	10				
	81			45	35			
	1		22	20	35			
	2			53	33			
	3		23	27	34			
	82		24	3	36			
	1			38	35			
	2		25	14	36			
	3			49	35			
	83		26	25	36			
			27	30	...	......		Stop. Wolverhampton.
			31	42	...	......		Start.
	2		32	59				
Level	3		33	46	47	......	19·15	
	84		34	25	39	......	23·07	
Fall $\frac{1}{330}$	1	2	34	58	33	......	27·27	
	2		35	28	30	......	30·00	
	3			57	29	......	31·03	
	85		36	25	28	......	32·14	
	1			52	27	......	33·33	
	2		37	17	25	26	34·61	
	3			44	27			
	86		38	8	24	24·5	36·73	
	1			32	24			
	2			57	25			
	3		39	22	25			
	87			47	25			
	1		40	11	24			
Fall $\frac{1}{532}$	2			37	26	......	34·61	
	3		41	3	26	......	34·61	
	88			30	27	27	33·33	
	1			57	27			
	2		42	24	27			
	3			51	27			
	89		43	18	27			
	1			45	27			
	2		44	13	28			
	3			39	26			
	90		45	6	27			
	1			33	27			
	2		46	0	27			
	3			28	28			
	91			54	26			
	1		47	20	26	25·35	35·48	
	2			47	27			
	3		48	11	24			
	92			37	26			
	1		49	3	26			
	3			54	51			
	93		50	19	25			
	1			43	24			
	2		51	8	25			
Level	3			33	25			
	94			58	25	......	36·00	
	1		52	23	25	......	36·00	
	2			48	25	......	36·00	
Rise $\frac{1}{367}$	3		53	15	27	......	33·33	
	95			42	27	......	33·33	
	1		54	12	30	......	30·00	
	2			42	30	......	30·00	
	3		55	14	32	......	28·12	
	96			46	32	......	28·12	
	1		56	20	34	......	26·47	
			57	10				Stop. Vauxhall Station, Birmingham.

Consumption of Coke.

616 pounds used to get up steam in the morning, and to fill up the firebox previous to starting	To be added in the second trip.	
Quantity of coke consumed during the trip of 95 miles, *inclusive* of what was required to fill up the firebox at the end of the journey	3654	lbs.
Coke consumed per mile	38·4	lbs.
Ditto per ton per mile upon the load (nett)	·55	lbs.

Intervals.	Dist. in miles.		Water evaporated.	Water evaporated.		
				Per mile.	Per hour.	
			Gallons.	Gallons.	Cubic ft.	
From Liverpool to Warrington...	18	......	393	21·83		337 cubic ft. water evaporated by 3654 lbs. coke = 1 cub. ft. water per 10·84 lbs. coke.
Warrington to Crewe	24	......	555	23·12		
Crewe to Stafford...........	24¾	......	519	20·97		
Stafford to Whampton......	14¾	......	396	26·84		
Whampton to Birmingham	13½	......	245	18·15		
	95		2108	22·19	93·2	

Statement of the time occupied in performing a trip from Liverpool to Birmingham, 95 miles, on an average rise of 1 in 2462, and of the time lost in stoppages and slackening and getting into the speed at the Stations.

No. of col.				Lost.		h	m	s
	Started from Liverpool........................ h 10 m 28 s 12 Arrived in Birmingham .... 2 57 10 } inclusive of stoppages.					4	28	58
	TIME LOST ON THE ROAD.	m	s	m	s			
1	Getting up speed at Liverpool, 1¼ to 4 miles, = 2¾ miles	6	41					
	At full speed would have been	4	20	2	21			
2	Slackened speed at Sutton, &c., 11¼ to 14¾ miles, = 3½ miles...	9	8					
	At full speed...	5	51	3	17			
2	Stoppage, &c. at Warrington, 19¾ to 21¾ miles, = 2 miles ...	39	4					
	At full speed	4	16	34	48			
3	Stoppage, &c. at Hartford, 31½ to 33½ miles, = 2 miles	9	34					
	At full speed	4	0	5	34			
5	Stoppage, &c. at Crewe, 43¼ to 45¼ miles, = 2 miles	12	8					
	At full speed...	4	56	7	12			
6	Slackened at Whitmore, 53½ to 55½ miles, = 2 miles	5	34					
	At full speed...	4	0	1	34			
8	Stoppage, &c. at Stafford, 67¾ to 69¾ miles, = 2 miles	13	33					
	At full speed...	5	4	8	29			
10	Stoppage, &c. at Whampton, 83 to 85 miles, = 2 miles	10	0					
	At full speed...	4	0	6	0			
12	Slackened at Birmingham, 96 to 96½ miles, = 2 miles............	1	24					
	At full speed...	1	0		24	1	9	39
	Time which would have been occupied if the Train had started from Liverpool at full speed, and travelled from thence to Birmingham without stopping					3	19	19

Equal to an average speed of 28·60 miles per hour.
Up an average rise of 1 in 2462.
Time, exclusive of *dead stoppages*, 3 hours 37 minutes.

"Hecla," Tender and Twelve Carriages.

From Birmingham to Liverpool.

Gradient.	Mileposts.		Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
			h	m	s				
Fall $\frac{1}{367}$			4	47	30				
	1			49	27				
		1		50	19	52	......	17·30	
		2			58	39	......	23·07	
		3		51	32	34	......	26·47	
	2			52	4	32	......	28·12	
		1			33	29	......	31·03	
		2		53	0	27	27·5	32·73	
		3			28	28			
Level	3				55	27	27·5	32·73	
		1		54	23	28			
		2			51	28	......	32·14	
Rise $\frac{1}{332}$		3		55	20	29	......	31·03	
	4				50	30	......	30·00	
		1		56	21	31	......	29·03	
		2			53	32	......	28·12	
		3		57	25	32	......	28·12	
	5				57	32	......	28·12	
		1		58	30	33	32·9	27·35	
		2		59	2	32			
		3			32	30			
	6		5	0	6	34			
		1			39	33			
		2		1	13	34			
		3			47	34			
	7			2	20	33			
		1			53	33			
		2		3	25	32			
		3			58	33			
	8			4	30	32			
		1		5	3	33			
		2			35	32			
		3		6	9	34			
	9				42	33			
		1		7	16	34			
		2			49	33			
		3		8	22	33			
	10				55	33			
Rise $\frac{1}{330}$		1		9	28	33	33·	27·27	
		2		10	1	33			
		3			34	33			
	11			11	10	36	35·9	25·07	
		1			46	36			
		2		12	22	36			
		3			57	35			
	12			13	33	36			
		1		14	10	37			
		2			45	35			
		3		15	22	37			
	13				58	36			
		1		16	33	35			
Level		2		17	7	34	......	26·47	
		3			39	32	......	28·12	
			h	m	s				
Fall $\frac{1}{350}$	14		5	18	20	41	......	21·95	
		1			55	35	......	25·71	Wolverhampton.
				22	8	...	......	......	Stop.
				23	12	...	......	......	Start.
		2		24	3				
		3			43	40	......	22·50	
	15			25	19	36	......	25·00	
		1			52	33	......	27·27	
		2		26	22	30	......	30·00	
		3			50	28	......	32·14	
	16	1		27	41	51	......	35·30	
		2		28	7	26	......	34·61	
		3			33	26	24·5	36·75	
	17				56	23			
		1		29	20	24	24·05	37·41	
		2			44	24			
		3		30	8	24			
	18				32	24			
		1			56	24			
		2		31	19	23			
		3			45	26			
	19			32	8	23			
		1			32	24			
		2			56	24			
		3		33	20	24			
	20				44	24			
		1		34	9	25			
		2			32	23			
		3			56	24			
	21			35	19	23			
		1			44	25			
		2		36	9	25			
Fall $\frac{1}{440}$		3			33	24	24·5	36·75	
	22				58	25			
		1		37	23	25	24·5	36·75	
		2			47	24			
		3		38	12	25	25·25	35·64	
	23				38	26			
		1		39	4	26			
		2			28	24			
Level		3			54	26	......	34·61	
	24			40	20	26	......	34·61	
		1			48	28	26·5	33·97	
		2		41	13	25			
		3			38	25	26·5	33·97	
Rise $\frac{1}{400}$	25			42	6	28			
		1			32	26	......	34·61	
		2			57	25	......	36·00	
		3		43	21	24	24·5	36·75	
	26				46	25			
		1		44	10	24	24·5	36·75	
		2			35	25			
	27			45	23	48	......	37·50	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Level	1	5	45	48	25	......	36·00	
	2		46	14	26	......	34·61	
Fall $\frac{1}{656}$	3			40	26	......	34·61	
	28		47	7	27	26·5	33·97	
	1			33	26			
	2		48	1	28	......	32·14	
	3			31	30	......	30·00	
			49	35	...	......	....	Stop. Stafford.
			52	0	...	......	....	Start.
	29 1		54	1				
Rise $\frac{1}{2103}$	2			59	58	......	15·51	
	3		55	44	45	......	20·00	
	30		56	24	40	......	22·50	
	1		57	6	42	......	21·43	
	2			42	36	......	25·00	
	3		58	17	35	......	25·71	
	31			50	33	......	27·27	
	1		59	22	32	......	28·12	
	2			53	31	31	29·03	
Rise $\frac{1}{303}$	3	6	0	24	31			
	32			55	31			
	2		1	57	62	......	29·03	
	3		2	27	30	31	29·03	
	33			59	32			
	1		3	30	31	31·3	28·75	
	2		4	1	31			
	3			33	32			
	34		5	4	31			
	1			34	30			
	2		6	6	32			
	3			37	31			
	35		7	9	32			
	1			40	31			
	2		8	12	32			
	3			43	31			
	36		9	15	32			
	1			46	31			
Rise $\frac{1}{650}$	2		10	17	31	31	29·03	
	3			48	31			
	37		11	19	31			
	1			51	32	31·5	28·56	
	2		12	22	31			
	3			53	31	31	29·03	
	38		13	24	31			
	1			55	31			
	2		14	26	31			
Rise $\frac{1}{390}$	3			58	32	......	28·12	
	39		15	30	32	......	28·12	
	1		16	3	33	33	27·27	
	2			35	32			
	3		17	9	34			
	40			42	33			
	1		18	15	33			
	2			48	33			
Rise $\frac{1}{390}$	3		19	21	33	33	27·27	
	41			54	33			

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Rise $\frac{1}{390}$	1	6	20	28	34	34	26·47	
	2		21	2	34			
	3			36	34	34·25	26·28	
	42		22	12	36			
	1			45	33			
	2		23	19	34			
	3			54	35	......	25·71	
	43		24	51	57			
			25	5	...	......	....	Stop. Whitmore.
			27	52	...	......	....	Start.
	1		29	44				
	2		30	44	60	......	15·00	
Level	44		32	9	85	......	21·16	
Fall $\frac{1}{330}$	1			43	34	......	26·47	
	2		33	14	31	......	29·03	
	3			44	30	......	30·00	
	45		34	12	28	......	32·14	
	1			38	26	......	34·61	
	2		35	5	27	......	33·33	
	3			31	26	......	34·61	
Fall $\frac{1}{177}$	46			56	25	......	36·00	
	1		36	20	24	......	37·50	
	2			43	23	......	39·18	
	3		37	6	23	......	39·13	
	47			28	22	21·77	41·32	
	1			50	22			
	2		38	13	23			
	3			35	22			
	48			56	21			
	1		39	18	22			
	2			39	21			
	3		40	1	22			
	49			22	21			
Fall $\frac{1}{263}$	1			44	22	......	40·91	
	2		41	7	23	23	39·13	
	3			31	24			
	50			54	23			
	1		42	16	22			
	2			39	23			
	3		43	4	25			
	51			25	21			
	1			47	22	23	39·13	
	2		44	10	23			
	3			33	23			
	52			56	23			
Fall $\frac{1}{330}$	1		45	20	24			
	2			43	23			
	3		46	7	24	24	37·50	
	53			31	24			
	1		47	1	30	......	30·00	
	2			45	44	......	20·45	
Level			48	20	...	......	....	Stop. Crewe.
			51	45	...	......	....	Start.
	54		53	55				
	1		54	40	45	......	20·00	
	2		55	19	39	......	23·07	
	3			53	34	......	26·47	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Level	55	6	56	26	33	……	27·27	
	1			57	31	……	29·03	
	2		57	26	29	28·89	31·15	
	3			55	29			
	56		58	24	29			
	1			53	29			
	2		59	22	29			
	57	7	0	20	58			
	1			48	28			
	2		1	17	29			
Fall $\frac{1}{440}$	3			45	28	……	32·14	
	58		2	13	28	……	32·14	
	1			40	27	……	33·33	
	2		3	7	27	……	33·33	
	3			32	25	……	36·00	
Level	59			58	26	……	34·61	
	1		4	26	28	28	32·14	
	2			54	28			
	3		5	22	28			
	60			50	28			
Fall $\frac{1}{350}$	1		6	17	27	……	33·33	
	3		7	10	53	……	33·97	
	61			36	26	……	34·61	
Fall $\frac{1}{2200}$	1		8	0	24	25·5	35·30	
	2			27	27			
	3			53	26	……	34·61	
	62		9	21	28	……	32·14	
Fall $\frac{1}{400}$	1			48	27	……	33·33	
	2		10	14	26	26·43	34·05	
	3			40	26			
	63		11	7	27			
	1			33	26			
	3		12	26	53			
	64			53	27			
Level	1		13	19	26	……	34·61	
Fall $\frac{1}{330}$	2			46	27	……	33·33	
	3		14	16	30	……	30·00	
	65			48	32	……	28·12	
	1		15	20	32	34	26·47	
Fall $\frac{1}{1383}$	2			56	36			
	3		16	34	38	37	24·32	
	66		17	10	36			
Fall $\frac{1}{440}$	1			43	33	……	27·27	
	2		18	15	32	……	28·12	
	3			45	30	……	30·00	
	67		19	14	29	……	31·03	
Level	1			42	28	……	32·14	
	2		20	11	29	29	31·03	
	3			39	28			
	68		21	9	30			
Fall $\frac{1}{330}$	1			38	29	……	31·03	
	2		22	5	27	27·5	32·73	
	3			33	28			
	69		23	0	27	……	33·33	
	1			26	26	……	34·61	
Level	3		24	17	51	……	35·30	
Rise $\frac{1}{338}$	70	7	24	44	27	……	33·33	
	1		25	14	30	30·5	29·51	
	2			45	31			
	3		26	19	34	……	26·47	
Level	71			53	34	……	26·47	
	1		27	27	34	……	26·47	
Fall $\frac{1}{180}$	2		28	0	33	……	27·27	
	3			32	32	……	28·12	
	72		29	2	30	30·5	29·51	
	1			33	31			
Fall $\frac{1}{100}$	2		30	0	27	……	33·33	
Fall $\frac{1}{310}$	3			25	25	……	36·00	
	73 1		31	20	55	25·25	35·64	
	3		32	6	46			
	74			31	25	25·5	35·30	
	1			57	26			
Fall $\frac{1}{3474}$	2		33	24	27	27·44	32·79	
	3			52	28			
	75		34	19	27			
	2		35	14	55			
	76		36	9	55			
	1			37	28			
	2		37	4	27			
Fall $\frac{1}{308}$	77			59	55	27·66	32·53	
	1		38	27	28			
	2			59	32	……	28·12	
			40	30	……	……	……	Stop. Warrington.
Rise $\frac{1}{400}$	78	8	4	45				Start.
	1		5	38	53			
Rise $\frac{1}{3500}$	2		6	36	58	……	15·51	
Fall $\frac{1}{711}$	3		7	35	59	……	15·26	
	79		8	13	38	……	23·68	
	1			43	30	……	30·00	
	2		9	13	30	31	29·03	
	3			45	32			
Rise $\frac{1}{626}$	80		10	16	31			
	1			48	32	……	28·12	
	2		11	22	34	33	27·27	
	3			54	32			
	81		12	30	36	……	25·00	
	82 3		16	49	4·19	……	24·32	
	83		17	30	41	……	21·95	
XIV.	1		18	8	38	……	23·68	
	2			42	34	……	26·47	
	3		19	15	33	……	27·27	
Rise	84			46	31	……	29·03	
XIII = $\frac{1}{2762}$	1		20	16	30	……	30·00	
	2			46	30	……	30·00	
	3		21	15	29	……	31·03	
	85			43	28	……	32·14	
XII.	1		22	12	29	……	31·03	
	2			41	29	……	31·03	

TABLE (*continued*).

Gradient.	Mileposts.		Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.	Gradient.	Mileposts.		Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.
			h m s								h m s				
		3	8 23 12	31	……	29·03				3	8 30 50	43	……	20·93	*
Rise	86		47	35	……	25·71		Level	88		31 28	38	……	23·68	
XI		1	24 33	46	……	19·56		IX		1	32 5	37	……	24·32	
$\frac{1}{89}$		2	25 27	54	……	16·66			91		39 58	7·53	……	20·93	
		3	26 32	65	……	13·84		VI Rise		1	40 30	32	……	28·12	
	87		28 1	89	……	10·11	Slipping.			2	41 0	30	……	30· 0	
X.		1	8 29 17	76	……	11·84	*	$\frac{1}{1094}$ 1¼	95	¼	51 0	10·0	……	25· 5	Stopped.
Level		2	30 7	50	……	18·00									

* Interrupted by overtaking Liverpool and Manchester Train.

CONSUMPTION OF COKE.

	lbs.
Used during the trip of 95 miles, exclusive of what would have been required to fill up the firebox at the end of the journey	2790
Add the quantity of coke at first put in to get up steam and fill the firebox	616·
	3406·
Coke consumed per mile	35·8
Coke consumed per ton per mile	·51

CONSUMPTION OF WATER.

Intervals.			Water evaporated.	Water evaporated.		
				Per mile.	Per hour.	
			Gallons.	Gallons.	Cubic feet.	
From Birmingham to Wolverhampton	13¼	Rise.	311	23·04		300 cubic feet of water evaporated by 34·06 lbs. of coke. =1 cubic foot of water, by 11·35 lbs. of coke.
Wolverhampton to Stafford	14¾	Fall.	244	16·54		
Stafford to Crewe............	24¾	Rise & Fall.	452	18·26		
Crewe to Warrington	24	Fall.	439	18·29		
Warrington to Liverpool...	18	....	427	23·72		
Total	95		1873	19·71	85·7	

Statement of the time occupied in performing the trip from Birmingham to Liverpool, 95 miles, down an average descent of 1 in 2462, and of the time lost in stoppages, and slackening and getting into speed at the Stations.

No. of col.		h m s			h m s
	Started from Birmingham	4 47 30	inclusive of stoppages		4 3 30
	Arrived in Liverpool	8 51 0			
	TIME LOST ON THE ROAD.	m s		m s	
1	Getting up speed at Birmingham, ¼ to 2¼ miles, = 2 miles...	5 58			
	At full speed would have been..	3 40		2 18	
2	Stoppages at Wolverhampton, 13¾ to 15¾ miles, = 2 miles...	9 11			
	At full speed	4 0		5 11	
4	Stoppages, &c. at Stafford, 28½ to 31½ miles, = 3 miles	11 52			
	At full speed	6 0		5 52	
6	Stoppages, &c. at Whitmore, 42½ to 44½ miles, = 2 miles ...	9 55			
	At full speed	4 16		5 39	
7	Stoppages, &c. at Crewe, 53 to 55½ miles, = 2½ miles	10 55			
	At full speed	4 20		6 35	
10	Stoppages, &c. at Warrington, 77½ to 79½ miles, = 2 miles .	30 16			
	At full speed	4 0		26 16	
11 & 12	Delay arising from overtaking Train on Liverpool and Manchester Line, 87¾ to 95¾ miles, = 8 miles	20 10			
	At full speed	16 0		4 10	56 1
	Time which would have been occupied if the Train had started from Birmingham at full speed, and travelled from thence to Liverpool without stopping				3 7 29

Equal to an average speed of 30·40 miles per hour.
On an average descent of 1 in 2462.
Time, exclusive of *dead stoppages*, 3 hours and 30 minutes.

Table of the uniform speeds attained by the "Hecla," with a load consisting of the Tender and Twelve Carriages (= 70 tons, gross) on the several Gradients of the Grand Junction Railway.

Gradient.	Uniform Speed.		Mean.	Remarks.
	Liverpool to Birmingham.	Birmingham to Liverpool.		
	Miles per hour.	Miles per hour.	Miles per hour.	
Rise, 1 in 96	13·63	....	....	Speed not uniform.
1 in 177	22·25	....	22·25	
1 in 265	24·87	....	24·87	
1 in 330	25·45	25·07	25·26	
1 in 390	....	26·28	26·28	
1 in 400	26·47			

TABLE (*continued*).

Gradient.	Uniform speed.		Mean.	Remarks.
	Liverpool to Birmingham.	Birmingham to Liverpool.		
	Miles per hour.	Miles per hour.	Miles per hour.	
1 in 400	27·27	....	26·87	
1 in 505	....	28·75	28·75	
1 in 532	....	27·35	27·35	
1 in 590	....	27·27	27·27	
1 in 650	....	29·03	29·03	
Level	30·71	31·15	30·93	
Fall, 1 in 3474	....	32·79	32·79	First starting, and in better than average order.
1 in 1094	34·61	....	....	
1 in 650	32·58	....	32·58	
1 in 590	33·16	....	33·16	
1 in 532	34·30	....	34·30	
1 in 505	31·36	....	....	Bad coke.
1 in 440	....	35·64	35·64	
1 in 400	....	36·75	36·75	
1 in 330	36·73	37·41	37·07	
1 in 265	....	39·13	39·13	
1 in 177	....	41·32	41·32	

The principle of compensation will be however more directly tested by taking the mean speed in ascending each gradient, and the mean speed in descending them respectively, and comparing together the means of these severally with the mean speed on the levels. This is done in the following table:—

Gradient.	Speed.		Mean.
	Ascending.	Descending.	
One in	Miles per hour.	Miles per hour.	
177	22·25	41·32	31·78
265	24·87	39·13	32·00
330	25·26	37·07	31·16
400	26·87	36·75	31·81
532	27·35	34·30	30·82
590	27·27	33·16	30·21
650	29·03	32·58	30·80
		Level...	30·93

These results render it quite apparent that the gradients do possess the compensating power ascribed to them. The discrepancy existing among the mean values of the speed, is nothing more than what may be ascribed to casual variations in the moving power. This experiment also was made under very favourable circumstances, the day being quite calm. Without going into the details of the principle on which these remarkable results depend, it may be stated generally, that since the chief part of the resistance of a railway train depends on the atmosphere, and is proportional to the square of the velocity, a very small diminution in the velocity itself produces a considerable diminution in its square. A train, in ascending a gradient, may therefore relieve itself from as much atmospheric resistance as is equal to the gravitation of the plane by slackening its speed. If its speed be slackened so as to render the resistance equal to that which it would have upon a level, then the engine would have to work with a less evaporating power than on a level, inasmuch as the motion would be slower. In practice, therefore, it never can be needful to slacken the speed so much as to equalize the resistance with that upon the level. Supposing the evaporating power to remain the same, the speed need only be slackened, so that with the same evaporation an increased resistance can be overcome at a speed less than the level, but not so much less as would render the resistance equal to the level. This, in fact, is what takes place in practice, as is apparent from the results above given.

By comparing the average evaporation effected in the above experiment with the average speed, an approximate value of the mean pressure of steam on the pistons may be obtained.

Let $L =$ the stroke of the piston in feet,
$A =$ the area of the piston in square feet,
$n =$ the number of strokes of the piston per minute,
$\because 2nAL =$ the number of cubic feet of space through which the piston moves per minute.

Let $cLA =$ the clearage, or the space between the steam-valve and the piston at each end of the stroke,

$\because$ the volume of steam admitted to each cylinder through the steam-valve at each stroke will be $2nAL(1+c)$.

Let $W =$ the water in cubic feet admitted per minute in the form of steam to each cylinder,

Let $S =$ the number of cubic feet produced by a cubic foot of water at the density which the steam has in the cylinders,

Hence we shall have $WS = 2nLA(1+c)$.

And if $P =$ the pressure of steam in the cylinder in lbs. per square foot, we shall have

$$P = \frac{Wa}{2nLA(1+c)} - b,^{*}$$

where $a = 4347826$ and $b = 618$.

In the present case we have $L = 1{\cdot}5$, $A = 0{\cdot}853$. Let us take $c = 0{\cdot}05$.

The mean rate of evaporation per hour was 89·5 cubic feet of water. The rate per minute would then be 1·49 cubic feet. Hence, since half the steam is supplied to each cylinder, we shall have $W = 0{\cdot}745$.

The mean speed of the train being 30·93 miles per hour, the velocity in feet per minute was 2722. To find the velocity of the piston, this must be reduced in the ratio of the circumference of the driving wheel to twice the length of the stroke. But the driving wheel being 5 feet in diameter, its circumference will be 15·7 feet; and since $2L = 3$, the velocity of the piston will be

$$2722 \times \frac{3}{15{\cdot}7} = 520;$$

and the value of n will therefore be

$$n = \frac{520}{2L} = \frac{520}{3} = 173{\cdot}3.$$

Hence we obtain

$$P = \frac{0{\cdot}745 \times 4347826}{346{\cdot}6 \times 1{\cdot}5 \times 0{\cdot}853 \times 1{\cdot}05} - 618 = 6642.$$

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[*] See Lardner on the Steam-Engine, 7th edit., p. 514.

Hence the pressure per square inch was 46 lbs. If 14·5 lbs. be deducted for the atmosphere, there will remain 31·5 lbs. per square inch to overcome all the resistances, including those of the engine itself.

The sum of the areas of the pistons being 246 square inches, the total pressure upon them, after deducting the resistance of the atmosphere, was $246 \times 31{\cdot}5 = 7749$. If we allow 2 lbs. per square inch to represent the reaction of the blast pipe, the effective pressure will be 7257 lbs. This reduced to the contact of the driving-wheels with the rails by multiplying it by $\frac{3}{15{\cdot}7}$, will give 1386 lbs. as the whole tractive force expended on the gross load.

If 150 lbs. be deducted from this as representing the force expended on the engine itself, there will remain 1236 lbs. to represent the actual force expended in drawing the train, including the tender.

The weight of the train, including the tender, being in this case 70 tons, the ratio of the weight to the gross resistance will be 126 to 1, and consequently that will represent the mean angle of repose for a train of this magnitude moved at 31 miles an hour.

It may be useful to form an approximate estimate of the proportion in which the total tractive force of 1236 is distributed between the different sources of resistance. If we take the friction according to the results of the experiments detailed in the first part of this Report to be at the rate of 5·5 lbs. per ton of the gross weight of the load, the total amount of the friction of the train of twelve coaches and tender, weighing 70 tons, will be 385 lbs. Thus we shall have—

Friction proper of the load	385 lbs.
Atmospheric resistance	851 do.
Total resistance	1236 do.

It follows, therefore, that this train of twelve coaches, engine, and tender, moving down an inclined plane falling at the rate of 1 in 120, with a velocity of 30·90 miles an hour, would not be accelerated, and that to move it down planes of less inclination at the same speed would require an amount of tractive power to be exerted by the engine, which would depend on the inclination of the plane.

It was found in this experiment, that the mean evaporating power of the coke was at the rate of 1 cwt. of coke to 10 cubic feet of water, or 11·2 lbs. of coke per cubic foot of water. This consumption of fuel does not greatly exceed the common estimate for the consumption of coal in ordinary low-pressure boilers.

The results of this experiment are quite in accordance with those of all the other experiments which have been stated in this Report. Lighter and smaller trains, moving with the same speed, suffered greater resistance in proportion to their weight, or what amounts to the same, they acquired less speed with the same resistance.

Taking the same estimate of the friction proper, the following table exhibits the total resistances to which trains of different magnitudes were found in these experiments to be subject when moving at the speeds given in the fourth column, and the proportion in which these resistances are due to the different resisting influences respectively :—

Description of Train.	Weight.	Wind.	Speed.	Friction proper.	Atmospheric resistance.	Total resistance.
	tons.		m. per h.	lbs.	lbs.	lbs.
Twelve coaches and tender.	70	Calm..........	31	385	851	1236
Eight coaches.................	40¾	Dead calm...	31⅓	225	800	1025
Eight coaches.................	40¾	Fair wind....	26⅛	225	291	516
Six coaches....................	34⅓	Calm..........	35⅓	190	678	868
Six coaches....................	27½	Fair wind....	37½	151	404	555
Six coaches....................	27½	Fair wind....	34⅓	151	374	525
Six coaches....................	27½	Adverse wind	32⅓	151	404	555
Six coaches....................	27½	Adverse wind	27¼	151	374	525
Four coaches..................	20⅓	Fair wind....	38¼	114	402	516
Four coaches..................	20⅓	Fair wind....	23	114	145	259
Four coaches..................	20	Fair wind....	19	110	59	169
Four coaches..................	18	Fair wind....	33¾	100	321	421
Four coaches..................	18	Fair wind....	21¼	100	127	227
Four coaches..................	15⅓	Fair wind....	31¼	85	279	364

Upon a general view of the body of experimental researches which have been detailed in this Report, the following practical conclusions appear to be fully established:—

1. The resistance offered to the moving power by a railway train is not, as has been heretofore supposed, independent of the speed, but is augmented in a high proportion as the speed is increased.

2. If the carriages be unaltered in number, form, and magnitude, the resistance will be in the simple ratio of the load, the speed and other circumstances being the same.

3. If the train be increased by augmenting the number of carriages, the ratio of the resistance to the weight at the same speed, other things being the same, will be diminished.

4. The practice hitherto adopted of expressing the resistance on railways *as so many pounds per ton of the gross load* ought to be discontinued, since the resistance is not proportional to the gross load, and therefore such expression may lead to erroneous conclusions.

5. The resistance of ordinary loads transported on railways at ordinary speeds, more especially of passenger trains, is very much greater than has been heretofore assumed, being with heavy loads at least double the common estimate, and with light loads threefold greater.

6. That a considerable amount of the resistance, more especially in the case of passenger trains, is due to the resistance of the air, and therefore expedients (such as wheels of increased magnitude) to diminish the amount of the mechanical resistances are not likely to be attended with adequate advantage.

7. That the resistance due to the air appears to proceed from the effect of the entire volume of the train, and not to depend in any sensible degree on the form of its foremost end. Expedients, therefore, for attaching a sharp front to the engine are ineffectual and useless.

8. That the mathematical formulæ given in the first part of this Report, consisting of two parts,—one proportional to the gross weight of the load but independent of the speed, and the other proportional to the square of the speed—have given results in all the cases to which they have been applied in accordance with the experiments. Such formulæ may therefore be taken to represent the facts until further and more extended and varied experience shall show the corrections of which they may be susceptible.

9. That the resistance produced to railway trains moving at ordinary speeds,

by curves of a mile radius, is inappreciable, and therefore curves of a much shorter radius may be safely laid down.

10. That the mean amount of resistance to railway trains being so much above the estimate heretofore adopted by engineers, and the resistance from curves being so much less than their estimate of it, the practical principles on which they have generally acted in laying out lines of railway will require serious modifications, all of which fortunately will have a tendency to diminish the expense and difficulty attending the construction and the working of railways.

In consequence of the low estimate of the resistance and the high estimate of the effect of curves, which engineers in general have heretofore adopted, great expense has been incurred and difficulties encountered to obtain flat gradients and straight lines. In some cases the gradients have been so levelled as not to exceed from four to six feet per mile, and the lines have been rendered so straight, that the curves nowhere have so short a radius as a mile. From what has been proved in the present Report, it is evident that such lines of railway will afford no practical advantage over those which have been laid down with gradients of sixteen, twenty, or even twenty-five feet per mile, and on which curves of a mile or less radius have been allowed.

The writer of this Report cannot conclude it without acknowledging the liberal assistance he has received from the Grand Junction Railway Company, who supplied engines, carriages, and waggons, without charge, for the experiments; also from the Liverpool and Manchester Railway Company, who allowed many of the experiments to be made on their line.

Mr. Hardman Earle of Liverpool, has also been of the greatest assistance in conducting the experiments, several of which were suggested by him.

Similar acknowledgements are also due to Mr. Edward Woods, engineer to the Liverpool and Manchester Railway Company. This gentleman superintended and directed many of the most important experiments, and subsequently reduced and tabulated them, when the writer of this Report was prevented by professional business from being present.

Report on Railway Constants. By EDWARD WOODS.

IN the first Report, by Dr. Lardner, of the Committee appointed by the British Association to investigate the mean values of the resistance of trains moving upon railways, published in the eighth volume of the Transactions of the Association, the various modes proposed for ascertaining the amount of resistance to the tractive power were described, and their relative merits discussed.

The methods alluded to were—

1. By the dynamometer.
2. By observing the motion of a load down an inclined plane, sufficiently steep to give accelerated motion.
3. By putting the load in motion on a straight and level line of railway, so as to impart to it a certain known velocity, and then observing the rate of its retardation.
4. By a combination of the two preceding methods, as resorted to by Le Comte de Pambour.
5. By a plan proposed by Dr. Lardner, viz. selecting two inclined planes of

different acclivities, and observing the maximum loads which an engine can draw up those planes whilst exerting an equal tractive power.

At the time of the publication of their first Report the Committee had made a number of experiments in accordance with the second method,—that of observing the motion of trains down inclined planes of different degrees of acclivity, noting whether the motion were accelerated, uniform, or retarded. Although these preliminary experiments were limited in number, and tried under rather disadvantageous circumstances as respected the weather, the fact that resistance increased in a heretofore unsuspected degree, in proportion as the speed of the train increased, was satisfactorily established. In what ratio the increment took place, whether as the square or some other function of the velocity, could not be determined, the results presenting some trifling apparent discordances, in consequence of the varying effect of the wind which prevailed at the time of the experiments. In pursuing their inquiries at a subsequent period, the Committee have been more fully convinced of the soundness of the principle which guided them in the selection of the method they at first adopted, and they have accordingly continued to conduct their experiments in a similar manner, repeating them with various sizes of trains, at various velocities, on the Sutton incline of 1 in 89 on the Liverpool and Manchester Railway, and on the inclines of 1 in 177, 1 in 265, and 1 in 330, on the Grand Junction Railway.

It is to be regretted that the weather was not on all occasions perfectly favourable. In some instances, however, there was not a breath of wind to disturb the results, especially when engaged at the Sutton incline plane. Such results deserve great confidence, and are particularly valuable for determining the amount of friction, properly so called.

A few remarks are necessary on the principle of analysis, adopted with regard to the observations which appear in a tabular form at the end of this Report. The data given there or elsewhere in the Report are,—

1. The coefficient of gravity on the inclination of the plane.
2. The initial velocity of the train at some determinate point on that plane. This may be either *zero*, as when the train starts from a state of rest, or some *positive* quantity.
3. The terminal velocity at some other determinate point on the same plane.
4. The time elapsed in traversing the space intervening between those two points.
5. The space intervening.
6. The force of gravitation, which in this latitude is known to be represented by $32\frac{1}{6}$, the velocity in feet per second acquired by a body falling freely *in vacuo*, at the end of the first second.
7. The weight or mass of the train, exclusive of the wheels and axles.
8. The weight or mass of the train subject to rolling motion, viz. the wheels and axles.
9. The radius of the wheels.
10. The distance from the centre of the wheel to the centre of oscillation.

From these data, when accurately obtained, the resistance of the train can be determined with absolute precision, the method turning altogether upon a comparison between a certain fixed and standard force, the force of gravitation, and the observed force by which the train is impelled in its descent. If a body move down an inclined plane without encountering resistance, its velocity at any given depth below the level of the point where its motion first commences will be always equal to the velocity it would have acquired by a free vertical descent, through the same height. If, then, this standard velocity be compared with the observed velocity of a body which has moved down a similar inclined plane to the same point, but which does meet with resistance in its passage, we at once obtain the means of assigning what amount of resistance it has suffered.

Some persons have objected to this method, on the ground that the results hitherto obtained by it have not always been consistent with each other. Such inconsistencies, however, may be satisfactorily explained, either on the supposition of the data not having been correct, or, what is more probable, from the fact of the existence of unobserved causes of irregularity, such as the influence of favouring or adverse winds, and differences of friction of the carriages. It will hereafter be shown what a remarkable correspondence the motions of the same train exhibit when permitted to descend along the same plane from the same point of elevation, provided the atmosphere be perfectly calm. Such correspondence could only exist under the uniform operation of the same producing cause, and the absence of accidental causes; and we therefore conceive that no surer test can be applied to determine the mean resistance experienced by a train in moving from one point to another down an uniform inclination, than a comparison between the observed time of its passage and the time it would have occupied if resistance had been altogether removed.

There are three cases of the motion to which the same formula is equally applicable:—

1. When the motion is accelerated.
2. When the motion is uniform.
3. When the motion is retarded.

In the first case the coefficient (determined by the inclination of the plane) of gravity is greater than the coefficient of resistance, and therefore the quantity which must be added to the coefficient of gravity to represent the coefficient resistance is *negative*.

In the second case the coefficient of gravity is equal to the coefficient of resistance, and no correction is required.

In the third case the coefficient of gravity is less than the coefficient of resistance, and the addition to the coefficient of gravity is a *positive* one.

In all cases therefore the coefficient of resistance may be found, by adding to the coefficient of gravity a quantity (determined by considerations alluded to in the former Report) which is either negative, or equal to zero, or positive.

This quantity may be thus obtained:—Multiply the initial velocity (2) in feet per second by the time in seconds (4). From this product subtract the space (in feet) passed over (5), and divide the difference by $16\frac{1}{12}$ times the square of the time occupied (4). The quotient thus found must be subjected to a slight correction, owing to the rotation of part of the moving mass, which correction may be determined by reference to data Nos. 7, 8, 9, and 10.

The initial velocity multiplied by the time represents the space which the train would describe were that velocity to remain constant. In the case of uniform motion, the velocity *does* remain constant, and the product of the two numbers equals the space traversed. Their difference, and consequently the whole quantity dependent upon it, vanishes, and the coefficient of gravity becomes also the coefficient of resistance.

In accelerated motion the product of the numbers is less than the space traversed, and the quantity to be added to the coefficient of gravity is negative, indicating the amount by which the force of gravity exceeds that of the resistance. On the other hand, when the motion is retarded, the reverse takes place, and the quantity to be added is positive.

Under the condition of uniform motion we are enabled positively to pronounce what is the mean resistance for that particular velocity. When, however, the velocity is accelerated or retarded between the two points of observation, although the mean resistance is known, we cannot state whether that mean resistance is due to the mean velocity, or to some other velocity intermediate between the limits of the initial and terminal velocities, because experience has not yet assigned the law of the corresponding increments of resistance and speed. It will be sufficient for all practical, and even theoretical purposes, to assume the mean resistance as applying to the mean velocity, remarking that the calculations are chiefly made from observations where the initial and final velocities do not widely differ, thus reducing, as far as possible, the limits of error. A more considerable source of error arises from the difficulty of obtaining with precision the *initial* velocity, owing to our inability to measure the time of passing from stake to stake accurately to a small fraction of a second. To obviate this, a mean has been taken from the observed times of traversing one or two spaces, preceding and succeeding the post at which the actual velocity is required. The errors are thus diffused over a larger space, and rendered less sensible.

The carriages employed belonged either to the Grand Junction, or to the Liverpool and Manchester Company. The former were first class, the latter second class, but both kinds were closed at the top and sides, presented the same transverse section, were loaded to nearly the same gross weights, and in other respects were identical. It is next to impossible to obtain two carriages even of similar make, whose friction shall be exactly the same, and accordingly a slight difference was observed, and it was found on the whole that the mean friction of the Grand Junction carriages exceeded the mean friction of the Liverpool and Manchester carriages, a fact which may be accounted for by the latter having been in use for a longer period.

We shall now consider the results afforded by the tables under the following heads:—

1. The Evaluation of Friction proper.

2. The additional resistance produced by increase of speed in trains of different sizes.

3. The effect of modifying the form of frontage, and of otherwise altering the nature of the exterior surface of the train, as for instance, by closing up the spaces between the carriages, ascertaining also the effect of the engine (as regards its external configuration in diminishing the resistance).

1. *The Evaluation of Friction, properly so called.*—On the 23rd of August 1839, the weather being perfectly fine and calm, three Liverpool and Manchester first class carriages, weighing gross 14·8 tons, were allowed to descend the Sutton inclined plane from a state of rest, starting from a post numbered 0, and urged only by the force of gravitation. The experiment was repeated four times, and the train descended the plane from 0 to 22 post, a distance of 2420 yards, in the following times respectively:—

1st. 4 m 28 s. 2nd. 4 m 25 s. 3rd. 4 m 23 s. 4th. 4 m 22 s.

These results coincide so closely, that we may fairly consider the sum of the resistances to have been the same in all cases, or at any rate to have decreased in only a very slight ratio, in proportion as the axles became better lubricated by continued running.

The fourth experiment is chosen as the subject of calculation, to determine the resistance of the said carriages at very slow velocities. Five separate computations are made from observations of the times of descent from No. 0 to No. 1, No. 0 to No. 2, No. 0 to No. 3, No. 0 to No. 4, and No. 0 to No. 5 posts respectively.

	tons.
The weight of the train, exclusive of wheels and axles, was equal to	12·4
The weight subject to rolling motion, viz. the wheels and axles, was	2·4
Total	14·8

The radius of the wheels was 18 inches, and the distance from the centre of the wheel to the centre of oscillation was 10 inches. In accordance with these data, the quotient alluded to, page 249, must be corrected by multiplying it into the constant number 1·09.

Three Liverpool and Manchester First-class Carriages.

No. 0 Post to	Time occupied.	Space passed over.	Coefficient of gravity.	Coefficient of resistance.	Resistance.		Mean velocity.	
					In lbs. per ton.	Total.	Feet per second.	Miles per hour.
	seconds.	feet.						
1	52	330	·01098	·00271	6·07	89·8	6·34	4·32
2	73	660	·01098	·00259	5·80	85·8	9·04	6·16
3	89	990	·01098	·00250	5·60	82·9	11·12	7·58
4	104	1320	·01098	·00271	6·07	89·8	12·69	8·65
5	117	1650	·01098	·00281	6·29	93·1	14·10	9·61

At these slow velocities the atmosphere would not offer much resistance, and we may therefore practically consider the resistances assigned to be those of friction alone. One remarkable result will not escape the attention, viz. that the resistance *diminishes* until the train attains the speed of 7·58 miles per hour, after which it again increases, owing no doubt to the opposition of the air at the higher mean velocity. At 4·32 miles per hour the resistance was 6·07 lbs., whereas at 7·58 miles per hour it becomes only 5·60 lbs. per ton, showing a difference of $\frac{4}{10}$ lbs. of a lb. per ton. This fact, it is believed, has hitherto been unnoticed. The cause is owing to a more perfect lubrication of the axles at the higher speed, and depends probably upon the formation of a certain thickness of film of grease between the brass step and the upper surface of the journal which keeps the two surfaces more effectually apart. In consequence of the slow velocity the pressure of the step upon the journal has a longer time to act in effecting the displacement of the fresh grease which has been supplied from the box, and the result is a greater amount of friction.

We proceed to estimate the friction of the other description of carriages, viz. those belonging to the Grand Junction Company, and which were used in the experiments on the long planes of the Grand Junction Railway.

On the evening of the 12th of July, 1839, a train of eight second-class Grand Junction carriages, weighing gross 40·45 tons, was brought to the top of the Sutton inclined plane, and allowed to descend from a state of rest from the post numbered 0, as in the previously mentioned instance. The weather was perfectly calm and fine. The carriages had been previously in use throughout the day on the Grand Junction line, and the experiments made with them will be hereafter noticed. It is sufficient to observe, that the friction of these carriages would be reduced to its minimum by the work they had undergone.

The time of descent from 0 to 22 post was $4^{m}\ 34^{s}{\cdot}25$. As a check upon the results, an experiment made with the very same carriages, performed on the 8th July, and recorded in Table No. 6, may be referred to. In that instance, the time of descent through the same space was 4^{m} 51^{s}, indicating a slightly increased amount of friction. It is not thought necessary to enter into a calculation of their friction on the 8th July, inasmuch as the performances agree very closely; and with the view of comparison with other sets of experiments made on the same day, it is considered on the whole fairer to ascertain the friction on that day, viz. the 12th July.

Five computations are made from observations of the times of descent from No. 0 to No. 5 post.

	tons.
The weight of the train, exclusive of wheels and axles, was	34·05
The weight subject to rolling motion, viz. the wheels and axles, was	6·40
Total	40·45

The radius of the wheels was 18 inches, and the distance from the centre of the wheel to the centre of oscillation, 10 inches. In accordance with these data, the coefficient of correction for the quotient alluded to, page 249, is 1·088.

Eight Grand Junction Carriages = 40·45 tons.

No. 0 Post to	Time occupied.	Space passed over.	Coefficient of gravity.	Coefficient of resistance.	Resistance:		Mean resistance.	
					In lbs. per ton.	Total.	Feet per second.	Miles per hour.
	seconds.	feet.						
1	55	330	·01098	·00360	8·06	326·2	6·00	4·09
2	77	660	·01098	·00346	7·75	313·5	8·57	5·84
3	95	990	·01098	·00356	7·97	322·5	10·42	7·10
4	110	1320	·01098	·00360	8·06	326·2	11·09	7·56
5	123·5	1650	·01098	·00366	8·20	331·6	13·36	9·11

Here, as before, we find the friction diminishes, it being least when the speed averages 5·84 miles per hour. From both series of experiments we deduce the following conclusions, which will be adopted in the subsequent investigations:—

1. The friction was least when the train was moving at the rate of about 6 miles per hour.
2. The total resistance of the train was also *least* when moving at about 6 miles per hour, notwithstanding the effect of the atmosphere at that speed.
3. The mean resistance of the Liverpool and Manchester carriages was never less than 5·60 lbs. per ton.
4. The mean resistance of the Grand Junction carriages was never less than 7·75 lbs. per ton.

We shall call the friction of the Liverpool and Manchester carriages equal to 6 lbs. per ton, and that of the Grand Junction carriages equal to 8 lbs. per ton, numbers which represent nearly the mean of the computed measures of friction.

2. The second point of our inquiry is now to be considered, viz. the effect which accompanies an increased speed of the train, as regards the amount of resistance experienced. We shall first present an analysis of the experiments made on the Sutton plane when the air was perfectly calm. Some of these experiments have been before noticed and made use of for determining the friction of the trains, but all will be found detailed in the Tables numbered IV., V., VII., VIII.

To begin with the train of three Liverpool and Manchester carriages, which descended the Sutton plane on the 23rd August, 1839 (see Table, No. IV.). The weight and other particulars have been stated before. The train having acquired considerable speed, was observed to pass posts Nos. 5, 10 and 15, at the respective velocities of 27·50 feet, 34·73 feet, and 41·25 feet per second, the velocity having evidently been accelerated throughout. Three computations have been made from these data, in connection with the time occupied in traversing the distances between the posts, distances equal to 1650 feet in each case. The mean resistance having been computed, the mean velocity (found by dividing the distance in feet by the number of seconds occupied in passing over) is placed opposite in the table, and it is to this mean velocity that the resistance is presumed to refer.

Three Liverpool and Manchester Carriages = 14·8 tons.

Ground of experiment.	Time occupied.	Space passed over.	Initial velocity.	Coefficient of gravity.	Coefficient of resistance.	Resistance.		Mean velocity.	
						In lbs. per ton.	Total.	Feet per second.	Miles per hour.
Post.	seconds.	feet.	ft. per sec.						
5 to 10	50	1650	27·50	·01113	·00367	8·22	121·6	33·00	22·50
10 to 15	43	1650	34·73	·01113	·00539	12·07	178·6	38·37	26·16
15 to 20	38	1650	41·25	·01113	·00726	16·26	240·7	43·42	29·60

The friction of the train of eight Grand Junction carriages was determined from an experiment on the Sutton incline (Table, No. V.). The resistance at higher speeds may be deduced from the same experiment. In this resistance, as in the case of the Liverpool and Manchester train, the carriages started from a state of rest, at No. 0 post, and were accelerated to the foot of the plane.

Eight Grand Junction Carriages = 40·45 tons.

Ground of experiment.	Time occupied.	Space passed over.	Initial velocity.	Coefficient of gravity.	Coefficient of resistance.	Resistance.		Mean velocity.	
						In lbs. per ton.	Total.	Feet per second.	Miles per hour.
Post.	seconds.	feet.	ft. per sec.						
5 to 10	54·75	1650	25·26	·01113	·00505	11·31	457·6	30·13	20·54
10 to 15	43·5	1650	34·30	·01113	·00547	12·25	495·6	37·93	25·86
15 to 20	38·0	1650	40·84	·01113	·00654	14·65	592·6	43·42	29·61

Bearing in mind that the friction of the two sets of carriages were respectively determined to be 6 and 8 lbs. per ton, it will be seen how considerably the resistance has augmented with the speed. The resistance experienced by the train of three carriages, when moving at 22·5 miles per hour, became 8·22 lbs. per ton; when at 26·16 miles per hour, 12·07 lbs. per ton; and when at 29·6 miles per hour, 16·26 lbs. per ton, or finally, more than double the resistance at 6 miles per hour. The resistance encountered by the train of eight carriages, when moving at 20·54 miles per hour, became 11·31 lbs.; when at 25·86 miles, 12·25 lbs.; and when at 29·61 miles per hour, 14·65 lbs. Here the ratio of the increase was less, owing to the greater weight of the train.

On the same evening, the 12th July, two other experiments were made with portions of the same train of carriages. A train of four carriages was provided, and after that a train of six carriages. These trains, instead of being allowed to descend quietly from the top of the plane, were impelled over the summit at the speeds of 33 and 26 miles per hour, by means of a locomotive engine, which on reaching the post No. 0, ceased to propel. The force of gravitation afterwards accelerated the speed down the plane. An examination of the respective rates of acceleration will give the means of determining the resistances in each case. See Tables, Nos. VII. and VIII.

Four Grand Junction Carriages = 20·45 tons.

Ground of experiment.	Time occupied.	Space passed over.	Initial velocity.	Coefficient of gravity.	Coefficient of resistance.	Resistance.		Mean velocity.	
						In lbs. per ton.	Total.	Feet per second.	Miles per hour.
Post.	seconds.	feet.	ft. per sec.						
0 to 10	64·50	3300	48·00	·01098	·00767	17·18	349·8	51·16	34·88
10 to 20	60·25	3300	53·33	·01120	·00958	21·46	438·8	54·77	37·34

Six Grand Junction Carriages = 30·45 tons.

Ground of experiment.	Time occupied.	Space passed over.	Initial velocity.	Coefficient of gravity.	Coefficient of resistance.	Resistance.		Mean velocity.	
						In lbs. per ton.	Total.	Feet per second.	Miles per hour.
Post.	seconds.	feet.	ft. per sec.						
0 to 10	76·75	3300	38·26	·01098	·00681	15·25	464·4	43·00	29·31
10 to 20	67·00	3300	46·32	·01120	·00825	18·48	561·2	49·25	33·58

We shall now examine the experiments made on the Grand Junction planes, and then present a summary of the results of the whole series. A moderate breeze blew directly down the plane during the course of the experiments. Its effects could not be accurately estimated, but as the wind acted to favour the descent of the train, the amount of resistance experienced and recorded must be less than could have been obtained in a calm state of the atmosphere. The error is on the right side for strengthening the force of the argument, which maintains the existence of an opposing power far exceeding what hitherto it had been supposed was encountered, and created as it were by the speed itself. At no very distant period in the history of railways, calculations were adduced before committees of the Houses of Parliament, to prove the dangerous tendency of permitting such gradients as 1 in 100 to be formed on any railway, and to show what an enormous and fearful acceleration would take place in the motion of a train if allowed to descend such planes without control. Even a plane of 1 in 177, it was supposed would demand a vigorous application of the brakes to limit the velocity within due bounds. In the infancy of the system, and the absence of extended experience, mistakes like these were natural. A valuation of the friction of carriages had been frequently made by various inquirers with a considerable degree of accuracy. They however overlooked in a great measure the influences brought into play by the rapidity of motion, and erred in forming too early generalizations from data still imperfect, applying the same standard to weigh the opposing forces, whether the train were proceeding at the speed of a steam-boat on the ocean, or winging its way through air with the swiftness of an eagle's flight.

The experiments described in this and the former Report show the fallacy of erecting theories and establishing formulæ on too slender a basis of facts. In a department of science, whose principles and laws are not yet fully developed, it behoves us to proceed upon a plan of the most cautious and rigid induction. Formulæ derived from mere theoretical considerations are of little value in reference to such a subject; but they may answer a more useful purpose when applied to express in a condensed form results between which an analogy has been traced, serving thus as the first steps of a generalization to be completed only by multiplying observations in every possible way.

On the 11th July, 1839, the eight second class Grand Junction carriages were taken to the planes, extending from Madeley to Crewe. The wind, as before noticed, blew *down* the plane. The train of eight carriages was thrice discharged over the head of the plane, at a speed varying from 23 to 26 miles per hour.

Secondly, one half the train, or four carriages, was dismissed over the head of the plane at 40·9 miles per hour; the other half, or four carriages, was dismissed at 32·73 miles per hour; and, lastly, a train of six carriages was dismissed at the speed of 25·57 *miles per hour*.

1. Eight carriages, weighing gross 40·75 tons, dismissed over the top of Madeley plane, 1 in 177, at 23·71 miles per hour, accelerated to 24·79 miles per hour, and varied between 24·79 and 23·54 miles per hour, until reaching the foot. See Table, No. IX.

2. Same train dismissed at 23·37 miles per hour, accelerated to 28·21, and varied between 28·21 and 25·77 miles per hour, until reaching the foot. See Table, No. X.

3. Same train dismissed at 26·39 miles per hour, accelerated to 27·05 miles per hour, and varied between 27·05 and 25·17 miles per hour, until reaching the foot. See Table, No. XI.

In the first case the maximum speed was attained at post No. 40; in the second case at post No. 48; in the third case at post No. 52. Let us compare the times of descent from post No. 40, for instance, to post No. 0 at the foot of the plane, and deduce from thence the average uniform speed over that distance of 4000 yards. The times were respectively,

5 min. 39·25 seconds = 24·1 miles per hour.
5 ... 8·25 ... = 26·4 ...
5 ... 18·50 ... = 25·6 ...

The mean of the whole is 25·4 miles per hour.

The circumstance of the speed having ceased to accelerate and having become uniform, renders unnecessary any calculation of the amount of resistance; for it has been already shown that, in the case of uniform motion, the coefficient of gravity is equal to the coefficient of resistance. The fraction $\frac{1}{177}$ in this instance then represents the coefficient of resistance; in other words, 12·65 *lbs. per ton was the mean resistance encountered by the train of eight carriages, when moving at the mean velocity of* 25·4 *miles per hour*.

Upon reaching the foot of the 177 plane, the trains passed on to a plane of 1 in 265, extending from the post numbered 0 to that numbered 54. The observations of its motion afford the means of ascertaining the resistance at a slower uniform velocity.

1. Eight carriages entered upon the 1 in 265 plane at 24·06 miles per hour; their motion was gradually retarded to 19·83 miles, over a space of about 3000 yards, and finally became uniform over the remaining distance.

2. Same carriages entered the plane at 25·76 miles per hour; their motion was retarded to 20·20 miles, over a space of 3000 yards, and finally became uniform, or nearly so over the remaining distance.

3. Same carriages entered the plane at 25·57 miles per hour; their motion was retarded to 19·02, over a space of 3500 yards, and finally became nearly uniform.

The times of passing from No. 30 to No. 54 posts, 2400 yards, were respectively,

4 min. 8·0 seconds = 19·7 miles per hour.
4 ... 5·75 ... = 19·9 ...
4 ... 20·50 ... = 18·9 ...

The mean of the whole is 19·5 miles per hour.

The force of gravity on the plane being expressed by $\frac{1}{265}$, 8·45 *lbs. per ton was the mean resistance encountered by the train of eight carriages, when moving at the mean velocity of* 19·5 *miles per hour.*

The train afterwards passed on to a plane of 1 in 330, but suffered throughout a gradual retardation, showing that the resistance exceeded the gravitating force on this plane. Were it deemed necessary a computation could readily be made of the resistance at still slower speeds from the observed rate of retardation, but this has already been determined from the Sutton experiments, which, from the absence of any disturbing effects produced by wind, are more to be depended upon.

The trains of four carriages next require our attention. The fact of so slight an acceleration as that from 23 to 25 miles per hour, having been produced during the descent of a plane more than 5000 yards in length, was sufficiently remarkable, and demanded an accurate verification. It was determined accordingly to make a sort of *experimentum crucis*, by dismissing the train from the head of the plane at a velocity considerably exceeding the maximum hitherto obtained during any portion of the descent, and to note whether, instead of further acceleration, an actual retardation would not take place. The event turned out as had been anticipated.

The four carriages were dismissed over the top at 40 miles per hour; their speed diminished; when half way down the plane it was reduced to 30 miles per hour; and by the time they reached the foot it did not exceed 25·17 miles per hour. See Table, No. XII.

The plane, it became evident, was too short to allow the train to acquire the uniform velocity due to the resistance, otherwise, in all probability, the speed would have been further lessened.

The remaining four carriages, composing a train of equal weight with the former, were now dismissed at 32·73 miles per hour. They were *retarded* to 22·72 miles per hour, and then continued uniform to the foot, over a space of 1600 yards. The time occupied in traversing the last 1600 yards was 2′ 23″ = 22·8 miles per hour. 12·65 *lbs. per ton was therefore the mean resistance encountered by this train of four carriages, when moving at the mean velocity of* 22·8 *miles per hour.*

At the top of the 1 in 265 plane the speed of the first set of four carriages was 25·17 miles per hour. This continued to decrease for 3400 yards, after which the motion became uniform at 19·2 miles per hour, indicating a resistance of 8·45 lbs. per ton.

The wind, which up to the time of the last experiment had blown in a direction to favour the motion of the trains down the plane, now veered round to the westward and fell on the sides of the carriages, tending to press the flanges of the wheel against the rails. This new source of resistance was soon rendered evident by the sluggish motion of the second train of four carriages in the latter part of its course (Table XIII.); also by that of a train of six carriages (Table XIV.), which afterwards descended; and lastly, by repeating the experiments with the entire train of eight carriages (Table XV.).

The Time Tables are given in the App. (see Tabs. XIII. XIV. XV.), but we deem it unnecessary to draw therefrom any numerical deductions with reference to the value of resistance. A comparison of the last trial of the train of eight carriages with the first three trials of the same train is well worthy of notice, as illustrating the powerful effects of a side wind. In the first case the mean initial velocity at the top was 24 miles per hour, and the mean final velocity at the foot, 25·4 miles per hour. Under the influence of a side wind, the initial velocity being 20·07 miles per hour, the final velocity at the foot was only 17·69 miles per hour, with the probability of a further retardation had the incline been longer.

The following Table presents a summary of the calculations we have made of the various amounts of resistance opposed to the different trains, on the localities and under the circumstances assigned.

Nature of the Train.	Weight of the Train.	Name of inclined plane where experiment was made.	Mean velocity.		Measures of resistance.		
			Feet per second.	Miles per hour.	Coefficient of resistance.	Pounds per ton.	Total.
	tons.						
3 L. & M. coaches...	14·80	Sutton 1 in 89	8·80	6·00	·00268	6·00	88·8
Ditto	14·8	Ditto	33·00	22·50	·00367	8·22	121·6
Ditto	14·8	Ditto	38·37	26·16	·00539	12·07	178·6
Ditto	14·8	Ditto	43·42	29·60	·00726	16·26	240·7
4 Gd. Jn. coaches...	20·45	Sutton	8·80	6·00	·00357	8·00	163·6
Ditto	20·45	Madeley	28·16	19·20	·00377	8·45	172·8
Ditto	20·45	Ditto	33·44	22·80	·00564	12·65	258·7
Ditto	20·45	Sutton	51·16	34·88	·00767	17·18	349·8
Ditto	20·45	Ditto	54·77	37·34	·00958	21·46	438·8
6 Gd. Jn. coaches...	30·45	Sutton	8·80	6·00	·00357	8·00	243·6
Ditto	30·45	Ditto	43·00	29·31	·00681	15·25	464·4
Ditto	80·45	Ditto	49·25	33·58	·00825	18·48	561·2
8 Gd. Jn. coaches...	40·45	Sutton	8·80	6·00	·00357	8·00	323·6
Ditto	40·45	Madeley	28·60	19·50	·00377	8·45	341·8
Ditto	40·45	Sutton	30·13	20·54	·00505	11·31	457·6
Ditto	40·45	Madeley	37·25	25·40	·00564	12·65	511·7
Ditto	40·45	Sutton	37·93	25·86	·00547	12·25	495·6
Ditto	40·45	Ditto	43·42	29·61	·00654	14·65	592·6

One of the important questions which the examination of such a series would suggest is, whether any relation can be traced between the speed and the excess of resistance produced by the speed, and to what extent this excess is modified by altering the size of the train. To enable the reader more readily to perceive what degree of connection subsists, the following table is constructed, presenting, in one column, the speed in miles per hour; in another, the weight and description of the train; and in a third, the excess of resistance in pounds per ton, or difference between the total resistance and the resistance due to friction alone, the whole being arranged in the order of increasing speed, grouping together experiments with trains of unequal sizes when their respective velocities were found nearly equal.

The excess of resistance, as exhibited in the fourth column, evidently increases with the speed. Thus, at 20·54 miles, the excess is 3·31 lbs.; at 25·86 miles, 4·25 lbs; at 29·61 miles, 6·65 lbs. per ton, in a train of eight carriages.

Speed in miles per hour.	Train.		Excess per ton of load.
	Number of Carriages.	Weight.	
		Tons.	Pounds.
19·20	4	20·45	0·45
19·50	8	40·45	0·45
20·54	8	40·45	3·31
22·50	3	14·8	2·22
22·80	4	20·45	4·65
26·16	3	14·8	6·07
25·40	8	40·45	4·65
25·86	8	40·45	4·25
29·60	3	14·8	10·26
29·31	6	30·45	7·25
29·61	8	40·45	6·65
34·88	4	20·45	9·18
33·58	6	30·45	10·48
37·34	4	20·45	13·46

In like manner, the excess at 29·31 miles per hour is 7·25 lbs., and at 33·58 miles, 10·48 lbs. per ton, in a train of six carriages.

So in a train of four carriages, at 22·8 miles, the excess is 4·65 lbs.; at 34·88 miles, 9·18 lbs.; and at 37·34 miles, 13·46 lbs. per ton.

In a train of three carriages, at 22·5 miles, the excess is 2·22 lbs.; at 26·16 miles, 6·07 lbs.; and at 29·60 miles per hour, 10·26 lbs. per ton.

The trains of four and eight carriages respectively, showed an excess of about half a pound only, but their motion was in some degree affected by the wind.

The excess of resistance per unit of the load increases as the size of the train diminishes, though not in the same proportion. This consequence would naturally be expected from the circumstance of an equal frontage being exposed to the air, whether the train consist, for instance, of three or eight carriages. Whatever resistance may be occasioned by the atmosphere acting on that frontage would in the one case be divided over three, and in the other over eight carriages. The fact of its not increasing in the same proportion proves that the train is subject to a resistance independent both of friction and mere frontage, and that in fact many complicated causes conspire to produce the entire resistance.

At the speed of 29 to 30 miles per hour there is a group of experiments made with three, six and eight coaches, which seems best to exhibit the effect alluded to. The increase of the train from three to six coaches, diminishes the excess per ton about 3 lbs., and increases the total excess of resistance in the proportion of 1 to 1½, not as 1 : 2, which is the proportion of the loads.

We do not, however, consider the observations to be as yet sufficiently numerous to warrant the foundation of any specific theory of resistance. The number of experiments in each group is extremely limited; some of the circumstances influencing the results, as for instance the wind, are not to be estimated, and therefore we deem it wiser to abstain from entering into the mathematical consideration of the laws which regulate the motion of solid bodies through a fluid medium until we can procure a *mean* from a large collection of groups of facts similar to those of which we have just afforded a specimen, otherwise we shall be in danger of having our inferences overturned by succeeding experiments, and discredit thrown upon the character of our inquiries.

The most important results are those relating to the train of eight carriages, because this load is the nearest approach to the average size of the ordinary passenger trains usually travelling upon railways. Thirty miles per hour is a fair average speed; and the resistance encountered by such a train moving at thirty miles per hour amounts, as we have already shown, to nearly 15 lbs. per ton, or almost double the value of friction only. These are results of an eminently practical tendency, indicating at what expenditure of power we can expect to be able to transfer a given load, and what degree of excess of power in the motive force, over and above the power required to overcome the friction, is necessary to the maintenance of an assigned rate of speed. The friction may no doubt be made less than 8 lbs. per ton by proper attention to the accurate fitting and perfect lubrication of the axles, and to the squareness with which they are placed on the framing, as indeed is made evident by the fact of certain carriages having run with a friction of only 6 lbs. per ton; but it is scarcely probable that a much lower amount will be attained, nor indeed would the reduction be of much importance in the economic working of passenger trains, which, from their high velocity, must necessarily bring into play large and independent sources of resistance.

Having ascertained the resistance to trains at various speeds, and under the circumstances in which they are found when employed in the regular traffic of the road, the attention of the Committee was earnestly directed to discovering how far any difference in the external configuration of the train, and modification of the form of the front or hind surfaces, or any alteration in the shape of the leading vehicle, might affect the resistance it experienced.

The information obtained in the course of this part of the inquiry is of a negative rather than a positive nature, proving that certain changes do *not* affect the resistance, but not satisfactorily pointing to any general principle whereby we can decide upon what the increase of resistance precisely depends.

The form of the front and the hind end of a train of carriages is flat, presenting an area of 62 square feet, including a sectional transverse measurement of the area of the axle and wheels, and springs and axle-boxes. To give the train the power of more readily cutting its way through the atmosphere, a sort of boat-shaped appendage was provided. Two boards, equal in height to the body of the carriage, were united in front, at an angle, the vertex being 5 ft. 6 in. before the flat front, and the base 6 ft. 6 in., corresponding with the width of the carriage. A single coach, weighing 5·37 tons, was dismissed from post No. 0, at the top of Sutton Plane, first with the prow applied in front, and afterwards without the prow.

The following Table is abstracted from Tables XVIII. and XIX. given in the Appendix :—

One Carriage 5·37 tons.	Total distance run.	Time occupied.	Time of descending Sutton Incline, 2420 yards.	Maximum speed.
	Yards.	m s	m s	Miles.
Pointed front......	3975	10 59	5 54	24·3
Flat front	3905	10 59	5 5	23·7
Differences	70	0 0	49	0·6

The difference is only seventy yards in a distance of more than two miles; the times of performing the distance precisely the same.

A train of eight carriages, weighing gross 40·75 tons, was dismissed from the top of Madeley Plane, both with the pointed front and the flat front; see Tables IX. and X. The following is an abstract:—

Eight Carriages = 40·75 tons.	Total distance run.	Time occupied.	Initial speed.	Time of descending.			Time of descending the three planes, 13,500 yards.
				1 in 177.	1 in 265.	1 in 330.	
	Yards.	m s	Miles.				
Pointed front …	14411	26 11½	23·7	8 4¾	8 50½	4 50¼	21 45½
Flat front ……..	14331	25 0¾	23·3	7 14¾	8 32¼	4 56¾	20 4¾
Differences ….	80	1 10¾	0·4	50	18¼	6½	1 1¾

The difference is only eighty yards in a distance of eight miles, and the other differences also far too small to establish any actual difference in the resistance.

The pointed prow was next applied to a train of three carriages, weighing gross 14·8 tons. This train was dismissed four times down the Sutton Plane. In the first and last trips the train descended without having the prow attached either before or behind, and in its ordinary state. In the second trip the prow was fixed *behind* the *last* carriage; in the third trip in *front* of the first carriage. The weather was perfectly fine and calm. The following results are abstracted from Tables I. II. III. IV. in the Appendix:—

Three Carriages = 14·8 tons.	Total distance run.	Time occupied.	Time of descending Sutton, 2420 yards.	Maximum speed.	Time of running the first 2¼ miles.
	Yards.	m s	m s	Miles.	
Pointed front ……	5576	13 1	4 23	32·1	7 30
Flat front and end.	5518	13 25	4 22	32·1	7 32
Differences ……	58	24	1	0·0	2
Pointed end …….	5350	13 45	4 25	31·0	7 50
Flat front and end.	5209	13 50	4 28	32·1	7 54
Differences ……	141	5	3	1·1	4

The differences are extremely slight, and such only as would have taken place with the same experiment repeated twice over. The pointed prow was placed at the back of the train, to test an opinion expressed by several individuals who were interested in the inquiry, that the resistance would in some measure be found to depend upon the shape of the hind surface of the last vehicle, and that if the end were pointed, the air would quickly and gently slide into the space just before occupied by the train, without causing so great a relative vacuum. The experiment showed that the pointed prow, whether placed behind the last carriage, or before the first carriage, exercised no appreciable influence on the rate of the train's motion, or on the resistance of which that motion was the index.

The next subject of inquiry was, whether the circumstance of the carriages being sent with their square ends foremost, instead of being preceded, as they usually are, by the engine and tender, was likely to throw any doubt upon the correctness of the values of resistance determined heretofore for the several trains of carriages.

The engine, it might be supposed, would act as a sort of cut-air to throw aside the current, and break its force before it reached the flat surface of the carriage. However improbable such a consequence might be after the indications just recorded, where a still more decided change of form was made the subject of trial, it was nevertheless determined to put the case to actual experiment. Accordingly a four-wheeled engine, the "Fury" and its tender, were weighted equal to two carriages. The pistons, connecting rods, and other working gear of the engine, were detached from the driving wheels, so that the engine should be subject to no other friction save that to which a carriage is subject. The grate-bars, ash-pan, &c. were removed, in order to make the engine as light as possible, and to assimilate its weight to that of a loaded carriage; two carriages were also prepared of equal weight. The Fury and tender were first dismissed down the Sutton Incline; afterwards the two carriages, and their times of descent compared.

The following is an abstract of the performances recorded in Tables XX. XXI.:—

Train.	Weight.	Total distance run.	Time occupied.	Time of descending Sutton Incline, 2420 yards.	Maximum speed.
	Tons.	Yards.	m s	m s	Miles.
Fury and tender	11·38	4710	11 37	4 45	29·0
Two carriages	11·33	4577	11 40	4 40	28·1
Differences	·05	133	0 3	0 5	0·9

The differences, as will be seen, are extremely slight. Each train was now increased by four carriages, and the contest took place between a train consisting of the Fury tender and four carriages, and a train of equal weight, consisting of six carriages. Tables XXII. and XXIII. may be referred to. The following is an abstract:—

Train.	Weight.	Total distance run.	Time occupied.	Time of descending Sutton Incline, 2420 yards.	Maximum speed.
	Tons.	Yards.	m s	m s	Miles.
Fury, tender and 4 coaches...	27·45	5068	12 9	4 49	30·5
Six coaches	27·45	4850	10 48	4 43	31·0
Differences		218	1 21	0 6	0·5

Here again there are no greater differences than might be expected with an experiment repeated twice over with the same train, and we may fairly conclude that the form of the front has no observable effect, and that whether the engine and tender be in front, or two carriages of equal weight, the resistance will be the same.

It has already been shown that at equal speeds, the excess of resistance, after deducting the friction, does not increase in the ratio of the load; a train of six carriages, at twenty-nine and a half miles, having experienced only one and a half times the resistance that a train of half that size at the same speed was subject to. This fact pointed to the conclusion that the excess of resistance observed at high speeds was due to something besides the mere extent of frontage, and this conclusion was confirmed by the experiment we are about to cite.

The front surface of a single carriage was enlarged by two side boards, each extending the whole height of the body of the carriage, and each being twenty inches in width. The surface thus added was equal to about twenty-two square feet; the total surface being therefore increased from sixty-two square feet to eighty-four square feet. The carriage was made to descend the Sutton Incline. See Tables XVI. and XVII. The following is an abstract:—

One Carriage = 5·37 tons.	Total distance run.	Time occupied.	Time of descending Sutton Incline, 2420 yards.
	Yds.	m s	m s
Enlarged front	3139	9 10	5 56
Ordinary front	3289	9 2	5 37
Differences	150	0 8	0 19

The differences are very slightly in favour of the ordinary front, but they are altogether so small as to prove that magnitude of frontage, independently of the general magnitude of the train, does not affect the resistance. From this point of view we shall be able to estimate in its true light the value of calculations of resistance to railway trains, deduced from *à priori* reasonings depending on such limited data as have been hitherto furnished by inquiries grounded on the force exerted by the atmosphere against the surface of bodies moving at various velocities.

There still remained an important point to decide. In a train of vehicles the front surface mainly encounters the brunt of the concussion with the air. The air, being displaced, is forced outwards towards the sides of the train; but it might be presumed, that, as the separate carriages composing the train are placed at an interval of perhaps three feet apart from each other, a relative vacuum would be produced behind the first carriage, causing a rush of air between the intervals, and until the equilibrium were restored a resistance over and above what would have been observed had no such interval existed. The same cause would take effect in like manner upon the second, third, and succeeding carriages, occasioning to each successively a slight resistance.

An experiment with a train of eight carriages on the Madeley Plane dissipated all doubt upon this head.

Round the corners of the ends of those carriages tenterhooks were nailed, and the intervals between the carriages were entirely closed up by closely woven canvas stretched tightly from carriage to carriage, and converting the whole train into one unbroken mass.

The train was allowed to descend the series of inclined planes between Madeley and Crewe. See Tables X. and XI.

Eight Carri' = 40·75 tons.	Total distance.	Time occupied.	Initial speed.	Time of descending.			Time of descending the three planes.
				1 in 177.	1 in 265.	1 in 330.	
	Yds.	m s	Miles.	m s	m s	m s	m s
With canvas	13967	24 35½	26·4	7 28½	8 46¼	5 31	21 46¼
Without canvas ...	14331	25 0¾	23·3	7 14¾	8 32¼	4 56¾	20 43¾
Differences	364	0 25	3·1	0 13¾	0 14½	0 34¼	1 2½

The result was in favour of the train *without* any canvas. The difference of total distance run in an eight miles journey was 364 yards; of time twenty-five and a quarter seconds; but, in fact, these differences are quite insignificant, and equal ones would no doubt have been observed had the train been allowed to descend twice over in the same condition. It is evident then that no appreciable change in the resistance arises from closing up the intervals between the carriages composing a train.

The inevitable inferences to be drawn from the foregoing experiments are:

1. That the resistance of a train is neither lessened nor augmented by changing the shape of its front or hind ends from flat to pointed surfaces, with the view of rendering it thereby more capable of cutting through the air.

2. That whether an engine and tender, or two carriages of equal weight, precede the train, the resistance is the *same*, and consequently the engine has no effect upon the air, similar to that which the bow of a ship has upon the water through which it is carried.

3. That increase of frontage, independent of any increase of the general magnitude of the train, does not increase resistance. This proposition, at least, must be considered as true within the limits of the surfaces which were actually submitted to experiment; the lesser surface being equal to the transverse section of a train suitable for a railway of 4 ft. 8½ in. gauge; the greater surface equal to the transverse section of a train suitable for a seven-feet gauge, such as the Great Western.

4. That no additional resistance is occasioned by leaving open spaces between the carriages, confining the intervals to the dimensions allowed in practice, and that no advantage is gained by converting the train into one unbroken column.

Having proved that the excess of resistance, after deducting friction, required for its estimation something besides the elements of the dimensions and form of frontage and of continuity of surface, it became an important subject of inquiry, what was the element, as yet not taken into account, which exerted the powerful influence observed.

The reader will doubtless have perceived that the subjects of the experiments hitherto described were carriages all of equal magnitude and of almost equal weight. When, however, the Committee first commenced their inquiry they made an experiment on the Madeley Planes with a train of five waggons. These waggons were loaded with iron chairs, so as to weigh precisely six tons each. They were constructed with high sides and ends, capable of being removed and laid flat upon the platforms of the waggons, so as to expose a greater or less bulk of carriage alternately to the air. When the sides were up, the whole frontage or transverse section, including the frames, wheels, springs, and axle, amounted to 47·8 square feet. When the sides were removed the transverse section was only 23·8 square feet, the surface being diminished by the area of the front board, whose dimensions were eight feet by three feet. The train, with its sides up, was placed at the 57th stake, at the summit of the plane falling one in 177, and was allowed to descend by gravity from a state of rest. It moved along the successive gradients, and finally stopped 10,019 yards from the point of its departure.

The sides were next removed and laid upon the platforms of the waggons, and the experiment was repeated. The train came to rest at 14,058 yards from the point of its departure.

Minute details of these two experiments will be found in the Eighth Report of the British Association for the year 1838. The value of the results was only properly understood after the course of the previously mentioned experiments had been completed, and the observations analysed. Frontage alone was before considered to have produced the additional resistance correspondent with the increments of speed, but it now became more than probable that such resistance was in a great measure dependent upon the *general volume of air* displaced. The weight of the displacing bodies in the instance before us was the *same*, but their volumes were to each other in a somewhat greater ratio than 2 to 1, and the effect is sufficiently remarkable. The train of least volume ran 4039 yards (or more than 2¼ miles) further than the train of greatest volume, both trains being allowed to descend by gravity from a state of rest from the same post on the Madeley Plane. This important fact appears to point out the path in which future investigations should be conducted.

The Committee have not had the opportunity of entering further upon it, but they recommend future experimentalists to direct their attention especially to the effects of increasing and diminishing the bulk of the trains, the weight remaining the same. Until more experiments of this nature have been obtained, we cannot expect to arrive at a complete and satisfactory theory of resistance.

One plain and practical inference to be drawn from the fact of the resistance being found to depend in a greater or less degree on the *volume* of air displaced in connection with the *rate* of displacement, is, that the less the space or bulk into which a given weight of train can be condensed, the less does the resistance at a given rate of speed become, and consequently the greater is the economy of moving power.

If the amount of resistance at present experienced at the ordinary rates of travelling be susceptible of diminution, the saving will probably be effected more by alteration in the *bulk* of the train than by attempting complicated changes in the mechanical construction of the carriages with the view of reducing the friction.

For the ordinary purposes of railway transport, we cannot, indeed, anticipate any very material reduction in the space occupied by the different vehicles, but we shall be warned of the consequences attending any attempt at enlarging their dimensions without rendering them at the same time capable of carrying a proportionally greater load. Especially we shall guard against the injurious consumption of moving power which may arise from the provision of more accommodation than is absolutely wanted. When the tide of traffic sets in one particular direction, it is impossible to avoid having the trains travelling in the opposite direction encumbered with a useless load of empty vehicles; but under ordinary circumstances it would seem practicable, by exercising due foresight, and by a judicious system of management, to apportion the profitable and unprofitable parts of the load more correctly and closely to each other.

In estimating the amount of moving power expended in working a line of railway, we have to consider,—

1. The character of the line, or nature of its gradients.
2. The weight as well as bulk of the train to be conveyed over it.
3. The speed at which the load is required to be conveyed.

If the resistance to each ton of load on a level railway could be represented by a constant quantity, at whatever speed the load were moved, it would become an easy matter to calculate the resistance to be overcome on any given line and length of railway, and to provide our power accordingly; for knowing the weight of the train, multiplying such weight by the coefficient of resistance, and this product by the length of road, we should at once obtain the resistance upon an equal length of level railway, and afterwards adding or subtracting, as the case might be, any increase or diminution of resistance, arising from ascending or descending gradients, we should obtain the total resistance. It would follow, then, that whether the load were transported at 5 or 50 miles per hour the expenditure of moving power would be the same. But we have already shown that no constant quantity will express the resistance. The resistance, in fact, is not dependent upon weight merely, but on speed also.

Of the three elements proposed as the basis of any computation, the first, viz. the character of the gradients, is fixed and unalterable. The second and third, viz. the weight and velocity, may be considered variable. When the dimensions of the engine are once fixed upon, the maximum of load is indeed limited by the tractive power of the engine and the steepest inclination it may have to ascend, and the speed is limited by the capability of the boiler to generate steam at the rate required, and of the density sufficient to overcome the resistance due to the speed. Within such limits the cases actually occurring in practice must be found to range. And according to the peculiar circumstances of the traffic, a high or low rate of speed, light or heavy trains will be adopted. Suppose the case of a perfectly level railway, on which a high average rate of speed has to be maintained. Since resistance is found to increase with the speed in an accelerated ratio, and since the boiler requires *time* for the generation of steam, a very considerable part of the maximum load which the engine could travel with at a slow speed must be thrown off to enable it to accomplish the higher rate. In other words, the load must be comparatively small; less, in fact, than the maximum on an ascending gradient of considerable acclivity. It does not often happen that the surface of a tract of country over which a railway is projected to pass is sufficiently free from inequality and variations of level as to admit a level or nearly level line to be constructed without entailing great expense in the formation of embankments, cuttings, and other works; and it therefore becomes a most important and interesting consideration, how far the expenses of moving power would be increased, and the velocity of transport diminished, by substituting a line of railway whose section shall be more conformable to the general outline of the country; a line consequently much less costly, but at the same time presenting a series of gradients, the inclinations of which should not be so steep as to render necessary any loss of motive power by application of the brakes during a descent.

As an abstract question of dynamics, the power expended (under the condition that the combined resistances of friction and the atmosphere are constant whatever the speed) would be the same for a train travelling between two given points on the same level, whether the road were level or undulating, making due allowance for the difference of distance traversed. On a level railway the speed of travelling would be uniform throughout, and the combined resistances alluded to would then, in calm weather, be constant throughout; but on an undulating railway the speed of the train would vary. And the question comes to this: Will the increased velocity on the descending gradients compensate for the time lost in the ascents? Will the *average* rate of speed over the whole line be different? In either case the load must manifestly be much smaller than the maximum which the engine could draw on the level at a slow speed. The engine will therefore be able to ascend the gradients of the undulating line merely by reducing its velocity, and thus relieving itself from as much of the excess of resistance, which exists in addition to friction, as may be necessary to enable the power again to equilibrate with the load. The inconvenience is only a reduction of speed during the ascents, and of course a loss of time upon the ascending gradient, as compared with the time that would have been occupied in conveying the train over an equal length of level.

Now, as by the hypothesis the terminal points of the railway are on a level with each other, the sum of the descents must be equal to the sum of the ascents. On the descents the force of gravity is brought into co-operation with the power exerted by the engine, and a speed would hence result greater than the speed which could be accomplished on the level. Although the Committee were fully aware that resistance increased in a greater ratio than speed, occasioning thereby some extra absorption of power on the descending gradients in making up for loss of time on the ascending ones, they were nevertheless strongly impressed by the consideration of this principle of compensation, and were of opinion that the loss of time on the whole journey would be but trifling, provided the gradients were not very unfavourable. To ascertain the value of this opinion, an experiment was made with the Hecla engine, tender, and a train of twelve carriages, weighing altogether 82 tons; and every precaution was used to obtain accuracy in the observation of velocity, consumption of fuel, and evaporation of water. The line chosen was the Grand Junction and part of the Liverpool and Manchester Railway. The point of departure was Liverpool, and the train was conveyed from thence to Birmingham and back, a total distance of 190 miles. The point of termination of the journey was therefore Liverpool, the train being brought again to the same level after traversing a long series of undulations.

The Table in the Appendix exhibits the time of passing the different quarter mile-posts, taken by a stop watch; also the variations in the inclinations of the road; the difference of time between the quarter mile-posts and the average speeds, as well as the particulars of stoppages for coke and water at the stations.

Collecting into one table the uniform speeds observed, both in ascending and descending the several gradients, and comparing the mean of these speeds with the average speed actually accomplished on the level portion (4 miles in length) northward of Crewe Station, we find an extraordinary coincidence in the results. The uniform rate of speed on the level was 30·71 miles per hour on the up-journey, 31·15 miles per hour on the down-journey; and the mean of the two is 30·93 miles per hour.

Gradient.	Uniform speed.		Mean.
	Ascending.	Descending.	
	Miles per hour.	Miles per hour.	Miles per hour.
1 in 177	22·25	41·32	31·78
265	24·87	39·13	32·00
330	25·26	37·07	31·16
400	26·87	36·75	31·81
532	27·35	34·30	30·82
590	27·27	33·16	30·21
650	29·03	32·58	30·80

Mean of all observations .... 31·22
Uniform speed on Level .... 30·93

Difference.................. ·29

The remarkable inference to be drawn from this table is, that a train of twelve carriages, drawn by the same engine, can be conveyed over a railway whose gradients range within the limits specified in the above Table, in the same time as it could over a perfectly level railway of equal length. In the

Appendix a statement is given of the time occupied in performing the trips, and of the time lost in stoppages, and in slackening and getting into speed at the stations. The difference between the two shows the time which would have been occupied if the train had started from Liverpool and Birmingham at full speed, and travelled between those places without stopping. This enables a comparison to be made between the *mean speed* on the *level*, and the average speed maintained by the train from its departure from Liverpool to its arrival at Liverpool again. An equal deduction for stoppages, and for loss of time in getting up speed, would have been necessary, had the line of road been level throughout.

The mean speed on the level was 30·93 miles per hour.

The time of performing the 190 miles, stoppages and delays deducted, was 6 hours, 26 minutes, 48 seconds.

If the 190 miles of road had been perfectly level, the time of performing the journey would have been (at the rate of 30·93 miles per hour) 6 hours, 8 minutes, 54 seconds.

In ordinary practice an engine of the dimensions of the Hecla would receive assistance up the Sutton, Whiston, and Warrington Incline Planes (1 in 89, 1 in 96, and 1 in 80). In the instance before us this was not the case, and the train had the disadvantage of encountering gradients not contemplated in our theory; whereby its speed sustained a loss not only in the ascents but in the descents also, when the power of the brake was applied to check the velocity. Taking all these attendant circumstances into account, we may conclude that the opinion entertained by the Committee was a correct one, viz. that trains whose weight bore an ascertainable relation to the nature of the gradients they had to traverse, could be made to traverse those gradients at an average speed equal to what the power of the engine could have accomplished on the level: that, for instance, a train of twelve carriages, representing the size of an ordinary train of passengers on the Grand Junction Railway, would travel over the existing gradients of that railway (saving perhaps the steeper ones of 1 in 96, &c. just alluded to) in as short a time as if the line had been absolutely level.

On some lines of road a train of twelve carriages may be a less, and on others a greater, than the average load which the conditions of traffic demand. The power of the engine (meaning by that term its evaporative as well as its tractive power) would then vary accordingly; or if the line were not already formed, the maximum gradient would be determined with reference to some standard form of engine, and to the probable size of the trains.

In the account of the Hecla's performance a correct statement is given of the fuel and water consumed on both trips. The average consumption of fuel, it will be seen, amounted to the rate of 37 lbs. per mile, which is reckoned on the entire quantity consumed during the day, including therefore all that was used for raising steam in the morning, and for keeping steam up during the intervals of rest. We shall not attempt to make an estimate of the *duty* done by the unit of coke or water in transporting the load, because there were no means of ascertaining the blast-pipe resistance, which it is believed formed a very considerable portion of the whole resistance the engine had to overcome, and because also later improvements in the locomotive engine have been introduced, which enable them to perform an equal duty with at least one-third less fuel.

For the Committee of the British Association,

June 1841. EDWARD WOODS.

APPENDIX.

July 11th and 12th, 1839.

GRAND JUNCTION AND LIVERPOOL AND MANCHESTER RAILWAYS.

Friction Experiments on Madeley and Sutton Incline Plane.

The Posts on Madeley Plane are placed 100 yards apart.

Descent from No. 57 to No. 0 post is 1 in 177.
Descent from No. 0 to No. 54 post is 1 in 265.
Descent from No. 54 to No. 78 post is 1 in 330.

Thenceforward the road is level.

Gravitating force on plane 1 in 177, 12·65 lbs. per ton.
Gravitating force on plane 1 in 265, 8·45 lbs. per ton.
Gravitating force on plane 1 in 330, 6·78 lbs. per ton.

Present {
Dr. Lardner.
Mr. Hardman Earle.
Mr. George Scott.
Mr. Garrick.
Mr. Evans.
Mr. N. Worsdell.
Mr. E. Woods.

Post 56 to 35 curves of one mile radius.
35 to 17 straight line.
17 to 6 curves of one mile radius.
6 to 0 straight line.
0 to 5 ditto.
5 to 11 curves of one mile radius.
11 to 22 straight line.
22 to 29 curves of one mile radius.
29 forwards, straight line.

August 23rd, 1839.—Table No. I.

Three Liverpool and Manchester First Class Carriages.

	tons.	cwts.	qrs.
Wellington	4	19	3
Peel	4	19	2
Diamond	4	12	1
Three Passengers	0	4	2
Gross weight . . .	14	16	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	4	24	0			
110	1			53	53	......	4·24
220	2		25	13	20	......	11·25
330	3			30	17	......	13·23
440	4			46	16		
550	5			58	12	14	16·07
660	6		26	10	12		
770	7			22	12	12	18·75
880	8			32	10		
990	9			42	10	10	22·50
1100	10			52	10		
1210	11		27	0	8		
1320	12			9	9	9	25·00
1430	13			18	9		
1540	14			26	8	8·5	26·47
1650	15			35	9		
1760	16				8		
1870	17			51	8	8·33	27·00
1980	18			58	7		
2090	19		28	6	8	7·5	30·00
2200	20			13	7		
2310	21			20	7	7	32·14
2420	22			28	8		
2530	23			36	8		
2640	24			44	8	8	28·12
2750	25	4	28	52·5	8·5		
2860	26		29	0	7·5	8	28·12
2970	27			9	9		
3080	28			18	9	9	25·00
3190	29			28	10		
3300	30			38	10	10	22·50
3410	31			49	11		
3520	32		30	0	11		
3630	33			11	11	11	20·45
3740	34			23	12	......	18·75
3850	35			36	13	......	17·30
3960	36			50	14		
4070	37		31	4	14	14	16·07
4180	38			19	15	......	15·00
4290	39			36	17	......	13·23
4400	40			54	18	......	12·50
4510	41		32	12·5	18·5	.....	12·16
4620	42			34	21·5	......	10·46
4730	43			58	24	......	9·37
4840	44		33	28	30	......	7·50
4950	45		34	6	38	......	5·92
5060	46		35	1	55	......	4·09
5170	47		36	29	88	......	2·54
5203	$\text{xiii}\frac{\text{i}}{\text{iv}}$		37	17			
5209	......			50			

Weather fine and perfectly calm.

In this experiment the carriages remained in the usual working state.

August 23rd, 1839.—Table No. II.

Three Liverpool and Manchester First Class Carriages, as before.

	tons.	cwts.	qrs.
Weight of Carriages and Load .	14	11	2
Three Passengers	0	4	2
Gross weight . . .	14	16	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	5 7 0				2750	25	5 11 48	7		
110	1	52	52	......	4·32	2860	26	58	10	8·5	26·47
220	2	8 13	21	......	10·71	2970	27	12 7	9		
330	3	30	17	......	13·23	3080	28	16	9		
440	4	45	15	......	15·00	3190	29	25	9	9	25·00
550	5	57	12	......	18·75	3300	30	35	10	......	22·50
660	6	9 9	12			3410	31	46	11		
770	7	19	10	11	20·45	3520	32	57	11	11	20·45
880	8	29·5	10·5			3630	33	13 8	11		
990	9	39	9·5	10	22·50	3740	34	21	13	12	18·75
1100	10	50	11			3850	35	34	13		
1210	11	58	8	9·5	23·68	3960	36	47	13	13	17·30
1320	12	10 7	9			4070	37	14 2	15		
1430	13	15	8	8·5	26·47	4180	38	17	15		
1540	14	24	9			4290	39	32	15	15	15·00
1650	15	32	8			4400	40	50	18		
1760	16		8	8·33	27·00	4510	41	15 8	18	18	12·50
1870	17	48	8		28·12	4620	42	28	20	......	11·25
1980	18	55·5	7·5			4730	43	50	22	......	10·22
2090	19	11 3	7·5			4840	44	16 15	25	......	9·00
2200	20	10·5	7·5	7·5	30·00	4950	45	45	30	......	7·50
2310	21	18	7·5			5060	46	17 21	36	......	6·25
2420	22	25	7	7·25	31·03	5170	47	18 6	45	......	5·00
2530	23	33	8			5203	XIII$\frac{\text{I}}{\text{IV}}$	20			
2640	24	....	8	8	28·12	5350	......	20 45			

Weather fine and perfectly calm.

In this experiment the Prow, or pointed end, was attached to the *back* of the last carriage of the train.

August 23rd, 1839.—TABLE No. III.

Three Liverpool and Manchester First Class Carriages, as before.

	tons.	cwts.	qrs.
Weight of Carriages and Load . . .	14	11	2
Three Passengers	0	4	2
Gross weight . . .	14	16	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	6 7 0				550	5	6 8 56	12		
110	1	52	52	......	4·32	660	6	9 8	12	12	18·75
220	2	8 12	20	......	11·35	770	7	19	11	......	20·45
330	3	29	17	......	13·23	880	8	29	10	......	22·50
440	4	44	15	......	15·00						

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
990	9	6	9	38·5	95		
1100	10			48	95	9·5	23·68
1210	11			58	10		
1320	12		10	6·5	8·5	9·25	24·32
1430	13			14·5	8		
1540	14			22	7·5		
1650	15			31	9	8·17	27·55
1760	16			......	8		
1870	17			47	8	8	28·12
1980	18			54	7		
2090	19		11	1·5	7·5		
2200	20			8·5	7		
2310	21			15	6·5	7	32·14
2420	22			23	8		
2530	23			30	7	7·5	30·00
2640	24			38	8		28·12
2750	25			46	8		
2860	26			54	8	8	28·12
2970	27		12	3	9		
3080	28			11·5	8·5		
3190	29			21	9·5	9	25·00
Yards.		h	m	s			
3300	30	6	12	30	9		
3410	31			40	10	9·5	23·68
3520	32			51	11		
3630	33		13	1	10	10·5	21·43
3740	34			12	11		
3850	35			23	11	11	20·45
3960	36			35	12	......	18·75
4070	37			48	13	......	17·30
4180	38		14	2	14		
4290	39			15	13	13·5	16·66
4400	40			30	15		
4510	41			45	15	15	15·00
4620	42		15	2	17		
4730	43			19	17	17	13·23
4840	44			38	19	......	11·84
4950	45		16	1	23	......	9·78
5060	46			24	23	......	9·78
5170	47			53	29	......	7·76
5203	XIII $\frac{\text{I}}{\text{IV}}$			59			
5576	......		20	1			

Weather fine and perfectly calm.

In this experiment the Prow, or pointed end, was removed from behind the train and now placed IN FRONT.

August 23rd, 1839.—TABLE No. IV.

Three Liverpool and Manchester Carriages, as before.

	tons.	cwts.	qrs.
Weight of Carriages and Load . . .	14	11	2
Three Passengers	0	4	2
Gross weight . . .	14	16	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	6	37	0			
110	1			52	52	......	4·32
220	2		38	13	21	......	10·71
330	3			29	16	......	14·06
440	4			44	15	......	15·00
550	5			57	13	......	17·30
660	6		39	8	11	......	20·45
770	7			18	10		
880	8			28	10	10	22·50
990	9			38	10		
1100	10			47	9		
Yards.		h	m	s			
1210	11	6	39	57	10		
1320	12		40	6	9	9·5	23·68
1430	13			14·5	8·5	......	26·47
1540	14			22·5	8	......	28·12
1650	15			30	7·5		
1760	16			...	8	7·75	29·03
1870	17			46·5	8·5		
1980	18			53	6·5	7·5	30·00
2090	19		41	1	8		
2200	20			8	7	7·5	30·00

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
2310	21	6 41 15	7			3850	35	6 43 24	11		
2420	22	22	7	7	32·14	3960	36	36	12	11·5	19·56
2530	23	29·5	7·5			4070	37	49	13	......	17·30
2640	24	38	8·5	8	28·12	4180	38	44 3	14		
2750	25		{ 8			4290	39	17	14	......	61·07
2860	26	54	8	8	28·12	4400	40	32	15	......	15·00
2970	27	42 3	9			4510	41	48	16	......	14·06
3080	28	12	9			4620	42	45 5	17	......	13·23
3190	29	21	9			4730	43	24	19	......	11·84
3300	30	30	9	9	25·00	4840	44	46	22		
3410	31	40	10	......	22·50	4950	45	46 8	22	22	10·22
3520	32	50·5	10·5			5060	46	36	28	......	8·03
3630	33	43 2	11·5	11	20·45	5170	47	47 8	32	......	7·03
3740	34	13	11	......	20·45	5203	XIII $\frac{\mathrm{I}}{\mathrm{IV}}$	16			
						5518	...	50 25			

Weather fine and perfectly calm.

In this experiment the carriages were restored to their usual working state.

July 12th, 1839.—TABLE No. V.

Eight Second Class Carriages.

	tons.	cwts.	qrs.
Weight of Carriages and Load	40	0	0
Six Passengers	0	9	0
Gross weight . . .	40	9	0

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Time.	Diffs.		Speed.
Yards.	.	h m s				Yards.		h m s			
0	0	7 52 0				1760	16	7 55 50	8·25	......	27·27
110	1	55	55	......	4·09	1870	17	57·75	7·75	......	29·03
220	2	53 17	22	......	10·22	1980	18	56 5	7·25		
330	3	35	18	......	12·50	2090	19	12·75	7·75	7·5	30·00
440	4	50	15	......	15·00	2200	20	19·75	7		
550	5	54 3·5	13·5	......	16·66	2310	21	27·5	7·75		
660	6	16	12·5	......	18·00	2420	22	34·25	6·75	7·17	31·39
770	7	27·25	11·25	......	20·00	2530	23	41·75	7·5		
880	8	38	10·75	......	20·93	2640	24	49·5	7·75	7·67	29·51
990	9	48·25	10·25	......	21·95	2750	25	57	7·5		
1100	10	58·25	10	......	22·50	2860	26	57 4·5	7·5		
1210	11	55 7·75	9·5	......	23·68	2970	27	13	8·5	7·83	28·72
1320	12	16·5	8·75	......	25·71	3080	28	22	9		
1430	13	25	8·5	......	26·47	3190	29	30·5	8·5	8·75	25·71
1540	14	34	9								
1650	15	41·75	7·75	8·37	26·86						

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
3300	30	7	57	39·25	8·75		
3410	31			49	9·75	9·25	24·32
3520	32			58	9		
3630	33		58	8	10		
3740	34			18	10	9·66	23·27
3850	35			29	11		
3960	36			40	11	11	20·45
4070	37			51·75	11·75		
4180	38		59	3·5	11·75	11·75	19·15
4290	39	7	59	16	12·5	......	18·00
4400	40			29	13	......	17·30
4510	41			43·25	14·25	......	15·79
4620	42			58	14·75	......	15·25
4730	43	8	0	14	16	......	14·06
4840	44			31·75	17·75	......	12·67
4950	45			51·5	19·75	......	11·39
5060	46		1	13	21·5	......	10·46
5170	47			38·5	25·5	......	8·82*
5203	xiii$\frac{1}{\text{iv}}$			47			
5485	......		4	19			

Dead calm.

* Stopped at XIII$\frac{\text{I}}{\text{IV}}$ mile post + 282 yards.

July 8th, 1839.—TABLE No. VI.

Eight Second Class Carriages, Nos. 12, 35, 5, 22, 9, 29, 30, 20.

	tons.	cwts.	qrs.
Weight of Eight Carriages and Load, at 5 tons each .	40	0	0
Three Passengers	0	4	2
Gross weight . .	40	4	2

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	9	1	0			
110	1			59·5	59·5	......	3·78
220	2		2	25	25·5	......	8·82
330	3			45	20	......	11·25
440	4		3	1	16	......	14·06
550	5			15	14	......	16·07
660	6			29	14		
770	7			41	12	13	17·30
880	8			52·5	11·5	......	19·56
990	9		4	2·5	10		
1100	10			12·5	10	10	22·50
1210	11			22·25	9·75	......	23·07
1320	12		....		9·50	......	23·68
1430	13			41	9·25	......	24·32
1540	14			49·5	8·5		
1650	15			58	8·5	8·5	26·47
1760	16		5	5·75	7·75		
1870	17			13	7·25	7·5	30·00
1980	18			21	8		
2090	19			29	8	8	28·12
2200	20			36·5	7·5		
2310	21			44	7·5	7·5	30·00
2420	22			51	7		
2530	23			58·5	7·5	7·25	31·03
2640	24		6	6	7·5	......	30·00
2750	25	9	6	14	8		
2860	26			22·5	8·5		
2970	27			30	7·5	8	28·12
3080	28			39·5	9·5		
3190	29			48·25	8·75		
3300	30			57	8·75	9	25·00
3410	31		7	7	10		
3520	32			17	10		
3630	33			27	10	10	22·5
3740	34			37·25	10·25	......	21·95
3850	35			48·5	11·25	......	20·00
3960	36		8	0	11·5	......	19·56
4070	37			12	12	......	18·75
4180	38			25	13		
4290	39			38	13	13	17·30
4400	40			53	15		
4510	41		9	7·5	14·5	14·75	15·25
4620	42			24	16·5	......	13·63
4730	43			42	18	......	12·50
4840	44		10	2	20	......	11·25
4950	45			25	23	......	9·78
5060	46			53	28	......	8·03
5170	47		11	25	32	......	7·03
5203	xiii$\frac{\text{I}}{\text{IV}}$			37	12		
5370	......		13	40			

Almost a dead calm.

July 12th, 1839.—Table No. VII.

Four Second Class Carriages, Nos. 30, 5, 20, 12.

	tons.	cwts.	qrs.
Weight of Carriages and Load	20	0	0
Six Passengers	0	9	0
Gross weight .	20	9	0

From initial velocity 33·64 miles per hour. Down Sutton Incline.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	4	6	20	53·5			
	3	....			6		
	2		21	6	6·5		
	1			12·5	6·5		
0	0			19·25	6·75	25·75	34·95
110	1			26·25	7		
220	2			32·75	6·5		
330	3			39·25	6·5		
440	4			46	6·75	26·75	33·64
550	5			52·5	6·5		
660	6			58·5	6		
770	7		22	5	6·5		
880	8			11·25	6·25	25·25	35·64
990	9			17·25	6		
1100	10			23·75	6·5		
1210	11			30	6·25		
1320	12			36	6	24·75	36·36
1430	13			42·25	6·25		
1540	14			48·25	6		
1650	15			54·75	6·5		
1760	16		23	0·5	5·75	24·5	36·73
1870	17			6	5·5		
1980	18			12·25	6·25		
2090	19			18	5·75		
2200	20			24	6	23·5	38·29
2310	21			30·25	6·25		
2420	22			36	5·75	6	37·50
2530	23			42·5	6·5		
2640	24			49	6·5		
2750	25	6			6·5	6·5	34·61
2860	26		24	2·5	7	7	
2970	27			9	6·5	6·75	33·33
3080	28			16·75	7·75		
3190	29			24·5	7·75		
3300	30			32·25	7·75	7·75	29·03
3410	31			40	7·75		
3520	32			48·25	8·25	8	28·12
3630	33			57	8·75		
3740	34		25	5·75	8·75	8·75	25·71
3850	35			15	9·25		
3960	36			24·25	9·25	9·25	24·32
4070	37			34·5	10·25	......	21·95
4180	38			45	10·5	......	21·43
4290	39			55·75	10·75		
4400	40		26	6·25	10·5	10·62	21·17
4510	41			18·25	12	......	18·75
4620	42			31·25	13	......	17·30
4730	43			45	13·75	......	16·36
4840	44			59·5	14·5	......	15·51
4950	45		27	15·25	15·75	......	14·28
5060	46			33	17·75	......	12·67
5170	47			52	29	......	11·84
5203	XIII $\frac{\text{I}}{\text{IV}}$			58			
5643	XIII $\frac{\text{I}}{\text{II}}$		29	40	*		
5869	......		32	0			

A light breeze from west, or down the Plane.

* Stopped at XIII $\frac{\text{I}}{\text{II}}$ mile post, + 226 yards.

July 12th, 1839.—Table No. VIII.

Six Second Class Carriages, Nos. 30, 5, 20, 12, 22, 29.

	tons.	cwts.	qrs.
Weight of Carriages and Load . .	30	0	0
Six Passengers	0	9	0
Gross weight	30	9	0

From initial velocity 26·47 miles per hour. Down Sutton Incline.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
-	4	7	23	31			
	3			38·5	7·5		
	2			46·75	8·25		
	1			55	8·25		
0	0		24	3·5	8·5	32·5	27·69
110	1			12·25	8·75		
220	2			20	7·75		
330	3			28·25	8·25		
440	4			36	7·75	32·5	27·69
550	5			44	8		
660	6			51·5	7·5		
770	7			59	7·5		
880	8		25	6	7	30	30·00
990	9			13	7		
1100	10			20·5	7·25		
1210	11			27·5	7·25		
1320	12			34·5	7	28·5	31·58
1430	13			41·25	6·75		
1540	14			48·25	7		
1650	15			55	6·75		
1760	16		26	1·75	6·75	27·25	33·02
1870	17			8	6·25		
1980	18			14	6		
2090	19			20·75	6·75		
2200	20			27·25	6·5	25·5	35·29
2310	21			34	6·75		
2420	22			40	6	6·38	35·29

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
2530	23	7	26	47	7		
2640	24			54	7		
2750	25			0·5	6·5	6·63	[illegible]
2860	26			7·5	7	……	[illegible]
2970	27			15	7·5	……	30·00
3080	28			23	8		
3190	29			31	8		28·12
3300	30			39	8	8	28·12
3410	31			47	8	……	26·47
3520	32			55·5	8·5	……	
3630	33		28	4·75	9·25		
3740	34			14	9·25		
3850	35			23·25	9·25	9·25	24·32
3960	36			33·5	10·25		
4070	37			43·75	10·25	10·25	21·95
4180	38			54·5	10·75	……	20·98
4290	39		29	5·5	11	……	20·45
4400	40			17·5	12	……	18·75
4510	41			30	12·5	……	18·00
4620	42			43·25	13·25	……	16·98
4730	43			57·25	14	……	16·07
4840	44		30	12·25	15	……	15·00
4950	45			29·25	17	……	13·23
5060	46			48	18·75	……	12·00
5170	47		31	8	20	……	11·25*
5203	$\mathrm{XIII}\frac{\mathrm{I}}{\mathrm{IV}}$			14			
5616			34	3			

Nearly calm.

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* Stopped at $\mathrm{XIII}\frac{\mathrm{I}}{\mathrm{IV}}$ mile post, + 413 yards.

July 11th, 1839.—Table No. IX.

Eight Second Class Carriages, Nos. 12, 35, 5, 22, 9, 29, 30, 20.

	tons.	cwts.	qrs.
Weight of Carriages and Load . . .	40	0	0
Ten Passengers	0	15	0
Gross weight .	40	15	0

Pointed end placed in front.

Initial velocity 23·71 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
	61	8 27 36·5			
	60	46·5	10		
	59	55·75	9·25		
	58	28 4·25	8·5		
0	57	13	8·75	36·5	22·41
	56	22	9		
	55	30·25	8·25		
	54	39	8·75		
	53	47·5	8·5	34·5	23·71
500	52	56	8·5		
	51	29 5	9		
	50	13	8		
	49	22	9	34·5	23·71
	48	30	8		
1,000	47	39	9		
	46	47·5	8·5		
	45	56·25	8·75	34·25	23·89
	44	30 4·25	8		
	43	13·25	9		
1,500	42	21·75	8·5		
	41	30	8·25	33·75	24·24
	40	38·5	8·5		
	39	47·25	8·75		
	38	55·25	8		
2,000	37	31 3	7·75	33	24·79
	36	12·25	9·25		
	35	20·25	8		
	34	...	8·25		
	33	37	8·5	34	24·06
2,500	32	46	9		
	31	54	8		
	30	32 2	8		
	29	10	8	33	24·79
	28	18·25	8·25		
3,000	27	...	8·5		
	26	35·25	8·5		
	25	44·25	9	34·25	23·89

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
3,300	24	8 32 53	8·75		
	23	33 1·25	8·25		
3,500	22	10	8·75		
	21	18·5	8·5	34·25	23·89
	20	27	8·5		
	19	36	9		
	18	44·75	8·75		
4,000	17	53·25	8·5	34·75	23·54
	16	34 2	8·75		
	15	10	8		
	14	19	9		
	13	27	8	33·75	24·24
4,500	12	36	9		
	11	44	8		
	10	53·25	9·25		
	9	35 1·75	8·5	34·75	23·54
	8	10	8·25		
5,000	7	18	8		
	6	27	9		
	5	35·25	8·25	33·5	24·24
	4	44	8·75		
	3	52·75	8·75		
5,500	2	36 1	8·25		
	1	9	8	33·75	24·24
	0	17·75	8·75		
	1	26	8·25		
	2	34·5	8·5		
6,000	3	43	8·5	34	24·06
	4	52	9		
	5	37 0	8		
	6	9·25	9·25		
	7	18	8·75	35	23·37
6,500	8	27·5	9·5		
	9	36·5	9		
	10	46	9·5		
	11	55·5	9·5	37·5	21·81

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
6,900	12	8 38 4·5	9			10,500	48	8 44 5·25	10·25		
7,000	13	14	9·5				49	15·5	10·25		
	14	23·5	9·5				50	26	10·5		
	15	33	9·5	37·5	21·81		51	36·5	10·5	41·5	19·71
	16	42·5	9·5				52	47·5	11		
	17	52·5	10			11,000	53	58	10·5		
7,500	18	39 1·75	9·25				54	45 8·25	10·25		
	19	11·5	9·75	38·5	21·25		55	19	10·75	42·5	19·25
	20	21·25	9·75				56	29·5	10·5		
	21	31	9·75				57	40·5	11		
	22	41	10			11,500	58	51·75	11·25		
8,000	23	51	10	39·5	20·71		59	46 2	10·25	43	19·02
	24	40 0·75	9·75				60	13·25	11·25		
	25	10·5	9·75				61	24·5	11·25		
	26	20·5	10				62	35·75	11·25		
	27	30·25	9·75	39·25	20·84	12,000	63	47·5	11·75	45·5	17·98
8,500	28	40	9·75				64	59·25	11·75		
	29	50·25	10·25				65	47 11	11·75		
	30	41 0·25	10				66	23	12		
	31	10	9·75	39·75	20·58		67	35	12	47·5	17·22
	32	20·5	10·5			12,500	68	47·25	12·25		
9,000	33	30·5	10				69	59·25	12		
	34	41	10·5				70	48 12·25	13		
	35	51·25	10·25	41·25	19·86		71	24·5	12·25	49·5	16·53
	36	42 1·25	10				72	37·75,	13·25		
	37	11·25	10			13,000	73	51·25	13·5		
9,500	38	21·75	10·5				74	49 4	12·75		
	39	32·25	10·5	41	19·95		75	...	13·25	52·75	15·51
	40	42·5	10·25				76	31	13·75		
	41	53·25	10·75				77	44·75	13·75		14·87
	42	43 3	9·75			13,500	78	58·5	13·75		
10,000	43	13·25	10·25	41	19·95						
	44	23·75	10·5			14,411		54 24·5			*
	45	34	10·25								
	46	44·75	10·75								
	47	55	10·25	41·75	19·60						

Breeze down the Plane.

* Stopped.

July 11th, 1839.—TABLE No. X.

Eight Second Class Carriages as before.

	tons.	cwts.	qrs.
Weight of Carriage and Load . . .	40	0	0
Ten Passengers	0	15	0
Gross weight .	40	15	0

Pointed end taken off.

From initial velocity 23·37 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	61	9	37	43			
	60			53·5	10·5		
	59		38	8	9·5		
	58			12·5	9·5		
0	57			21·25	8·75	38·25	21·39
	56			30	8·75		
	55			38	8		
	54			46	8		
	53			53·25	7·25	32	25·57
500	52		39	0	6·75		
	51			...	7·5		
	50			15	7·5		
	49			22·5	7·5	29·25	27·97
	48			29·5	7		
1000	47			36·5	7		
	46			44·25	7·75		
	45			51·5	7·25	29	28·21
	44			58·5	7		
	43		40	5·75	7·25		
1500	42			13·25	7·5		
	41			20·5	7·25	29	28·21
	40			27·75	7·25		
	39			35·25	7·5		
	38			43	7·75		
2000	37			50·25	7·25	29·75	27·50
	36			57·25	7		
	35		41	4·5	7·25		
	34			12	7·5		
	33			19·25	7·25	29	28·21
2500	32			27	7·75		
	31			34·5	7·5		
	30			42	7·5		
	29			49·25	7·25	30	27·27
	28			57	7·75		
3000	27		42	4	7		
	26			12·25	8·25		
	25			19·75	7·5	30·5	26·82
	24			27·5	7·75		
	23			35	7·5		
3500	22			43	8		
	21			51·25	8·25	31·5	25·97
Yards.		h	m	s			
3700	20	9	42	58·5	7·25		
	19		43	6·5	8		
	18			14·25	7·75		
4000	17			22·25	8	31	26·39
	16			30·25	8		
	15			38	7·75		
	14			46·25	8·25		
	13			......	7·75	31·75	25·77
4500	12		44	2	8		
	11			9·75	7·75		
	10			18	8·25		
	9			25·75	7·75	31·75	25·77
	8			33·5	7·75		
5000	7			41·25	7·75		
	6			49·5	8·25		
	5			57	7·5	31·25	26·18
	4		45	5	8		
	3			13	8		
5500	2			20·5	7·5		
	1			28·25	7·75	31·25	26·18
	0			36	7·75		
	1			44	8		
	2			52	8		
6000	3		46	0	8	31·75	25·76
	4			7·75	7·75		
	5			16	8·25		
	6			24	8		
	7			33	9	33	24·79
6500	8			41	8		
	9			50	9		
	10			58·5	8·5		
	11		47	7	8·5	34	24·06
	12			15·5	8·5		
7000	13			24·5	9		
	14			33	8·5		
	15			42	9	35	23·37
	16			51·25	9·25		
	17		48	0·25	9		
7500	18			...	8·75		
	19			18	9	36	22·73

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.	Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s				Yards.		h	m	s			
7700	20	9	48	27·25	9·25			10,900	52	9	53	47·25	10·75		
	21			36·5	9·25			11,000	53			58	10·75		
	22			46	9·5				54		54	8·25	10·25		
8000	23			55·5	9·5	37·5	21·81		55			19	10·75	42·5	19·25
	24		49	4·25	8·75				56			29·75	10·75		
	25			14·5	10·25				57			40·5	10·75		
	26			24·5	10			11,500	58			52	11·5		
	27			31·5	7	36	22·73		59		55	2·5	10·5	43·5	18·81
8500	28			43	11·5				60			13·75	11·25		
	29			52·75	9·75				61			25·25	11·5		
	30		50	2·5	9·75				62			36·5	11·25		
	31			12	9·5	40·5	20·20	12,000	63			48·75	12·25	46·25	17·69
	32			22·25	10·25				64		56	0·5	11·75		
9000	33			32·25	10				65			12·5	12		
	34			42·25	10				66			24·5	12		
	35			52·5	10·25	40·5	20·20		67			37	12·5	48·25	16·96
	36		51	2	9·5			12,500	68			50	13		
	37			12·25	10·25				69		57	2·5	12·5		
9500	38			22·25	10				70			15	12·5		
	39			32·25	10	39·75	20·58		71			28·5	13·5	51·5	15·89
	40			42·5	10·25				72			41·75	13·25		
	41			52·75	10·25			13,000	73			55·5	13·75		
	42		52	3	10·25				74		58	9	13·5		
10,000	43			13·25	10·25	41	19·95		75			...	13·5	54	15·15
	44			23·25	10				76			36·5	14		
	45			34	10·75				77			51	14·5		
	46			44·25	10·25			13,500	78		59	5	14		
	47			54·5	10·25	41·25	19·83	13,596				19·5	14·5	57	14·35
10,500	48		53	5	10·5			13,785				51·5			
	49			15	10			13,915		10	0	16			
	50			26	11			14,242			1	53·5			
	51			36·5	10·5	42	19·48	14,331			3	22		*	

Breeze down the Plane.

* Stopped.

July 11th, 1839.—TABLE No. XI.

Eight Second Class Carriages as before, the spaces between the Carriages being closed up with canvas.

	tons.	cwts.	qrs.
Weight of Carriages and Load	40	0	0
Ten Passengers	0	15	0
Gross weight	40	15	0

From initial velocity 26·39 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.	Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s				Yards.		h	m	s			
	61	12	17	44·25				3700	20	12	23	5	8		
	60			53·5	9·25				19			13	8		
	59		18	2	8·5				18			21·25	8·25		
	58			10	8			4000	17			29·5	8·25	32·5	25·17
0	57			17·75	7·75	33·5	24·42		16			38	8·5		
	56			25·25	7·5				15			46	8		
	55			33	7·75				14			54	8		
	54			40·5	7·5				13		24	1·75	7·75	32·25	25·37
	53			48·75	8·25	31	26·39	4500	12			10	8·25		
500	52			56	7·25				11			18	8		
	51		19	3·5	7·5				10			26	8		
	50			11·25	7·75				9			34	8	32·25	25·37
	49			19	7·75	30·25	27·05		8			42·25	8·25		
	48			26·5	7·5			5000	7			50·25	8		
1000	47			34·25	7·75				6			58	7·75		
	46			41·25	7				5		25	6	8	32	25·57
	45			49·75	8·5	30·75	26·61		4			14	8		
	44			57	7·25				3			22	8		
	43		20	4·5	7·5			5500	2			30	8		
1500	42			12	7·5				1			38	8	32	25·57
	41			20	8	30·25	27·05		0			46·25	8·25		
	40			27·75	7·75				1			54·25	8		
	39			35·25	7·5				2		26	2	7·75		
	38			43·25	8			6000	3			10	8	32	25·57
2000	37			51·25	8	31·25	26·18		4			18	8		
	36			58·5	7·25				5			26·5	8·5		
	35		21	6	7·5				6			35	8·5		
	34			14	8				7			43·5	8·5	33·5	24·42
	33			21·75	7·75	30·5	26·82	6500	8			52·25	8·75		
2500	32			30	8·25				9		27	0·5	8·25		
	31			37·5	7·5				10			9	8·5		
	30			45·25	7·75				11			18	9	34·5	23·71
	29			53·25	8	31·5	25·97		12			26·5	8·5		
	28		22	1	7·75			7000	13			35·25	8·75		
3000	27			8·5	7·5				14			44·25	9		
	26			16·5	8				15			53·25	9	35·25	23·21
	25			24·5	8	31·25	26·18		16		28	1·5	8·25		
	24			32·75	8·25				17			10·5	9		
	23			40·5	7·75			7500	18			19·25	8·75		
3500	22			49	8·5				19			28·75	9·5	35·5	23·05
	21			57	8	32·5	25·17								

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.	Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s				Yards.		h	m	s			
7700	20	12	28	38	9·25			10,900	52	12	34	10	11		
	21			47·25	9·25			11,000	53			21·25	11·25		
	22			56·25	9				54			33	11·75		
8000	23		29	5·25	9	36·5	22·41		55			44·5	11·5	45·5	17·99
	24			14·25	9				56			55·75	11·25		
	25			24	9·75				57		35	7·75	12		
	26			34	10			11,500	58			19·25	11·25		
	27			43·5	9·5	38·25	21·39		59			32	12·75	47·5	17·22
8500	28			53·25	9·75				60			44	12		
	29		30	2·5	9·25				61			55·75	11·75		
	30			12·5	10				62		36	8	12·25		
	31			22·5	10	39	20·98	12,000	63			21	13	49	16·69
	32			33	10·5				64			34·25	13·25		
9000	33			42·5	9·5				65			47·75	13·5		
	34			53·25	10·75				66		37	2	14·25		
	35		31	3·25	10	40·75	20·07		67			15	13	54	15·15
	36			14	10·75			12,500	68			29	14		
	37			24·5	10·5				69			43·25	14·25		
9500	38			35·25	10·75				70			58	14·75		
	39			46·25	11	43	19·02		71		38	13	15	58	14·10
	40			57	10·75				72			28·25	15·25		
	41		32	7·75	10·75			13,000	73			43·25	15		
	42			18·5	10·75				74			59	15·75		
10,000	43			29·5	11	43·25	18·91		75			......	16	62	13·19
	44			40·25	10·75				76		39	31	16		12·78
	45			51·75	11·5				77			47·5	16·5		
	46		33	2·5	10·75			13,500	78		40	4	16·5		12·39
	47			13·75	11·25	44·25	18·49	13,598				22	18		11·36
10,500	48			25	11·25			13,785			41	5			
	49			36	11			13,915				54·5			
	50			48	12			13,967			42	53·25			
	51			59	11	45·25	18·08								

Breeze down the Plane.

July 11th, 1839.—Table No. XII.

Four Second-Class Carriages, Nos. 5, 9, 29, 30.

	tons.	cwts.	qrs.
Weight of Carriage and Load	20	0	0
Three Passengers		4	2
Gross weight	20	4	2

From initial velocity 40·90 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	61	6	50	58			
	60		51	4	6		
	59			9	5		
	58			14	5		
0	57			19·5	5·5	21·5	38·04
	56			25	5·5		
	55			30·5	5·5		
	54			35·75	5·25		
	53			41·5	5·75	22	37·18
500	52			47	5·5		
	51			53	6		
	50			58	5		
	49		52	3·25	5·25	21·75	37·61
	48			9	5·75		
1000	47			14·25	5·25		
	46			20·25	6		
	45			26	5·75	22·75	35·96
	44			32·25	6·25		
	43			38	5·75		
1500	42			44	6		
	41			50·5	6·5	24·5	33·39
	40			56	5·5		
	39		53	2·25	6·25		
	38			8·25	6		
2000	37			15	6·75	24·5	33·39
	36			21·25	6·25		
	35			27·75	6·5		
	34			34·25	6·5		
	33			·······	6·5	25·75	31·77
2500	32			47·25	6·5		
	31			53·5	6·25		
	30		54	0	6·5		
	29			6·5	6·5	25·75	31·77
	28			13	6·5		
3000	27			20	7		
	26			27	7		
	25			34·25	7·25	27·75	29·48
	24			41·25	7		
	23			48·75	7·5		
3500	22			55·75	7		
	21		55	3	7·25	28·75	28·45
Yards.		h	m	s			
3700	20	6	55	10	7		
	19			17	7		
	18			25	8		
4000	17			32·5	7·5	29·5	27·73
	16			39·75	7·25		
	15			47·5	7·75		
	14			55	7·5		
	13		56	2	7	29·5	27·73
4500	12			9·75	7·75		
	11			17·25	7·5		
	10			25	7·75		
	9			32·75	7·75	30·75	26·61
	8			40	7·25		
5000	7			48	8		
	6			55·75	7·75		
	5		57	3·25	7·5	30·5	26·82
	4			11·25	8		
	3			19·25	8		
5500	2			27·25	8		
	1			35·25	8	32	25·57
	0			43·5	8·25		
	1			51·5	8		
	2		58	0	8·5		
6000	3			7·75	7·75	32·5	25·17
	4			16	8·25		
	5			24·5	8·5		
	6			33·25	8·75		
	7			42	8·75	34·25	23·89
6500	8			50·75	8·75		
	9		59	0	9·25		
	10			8·5	8·5		
	11			17	8·5	35	23·37
	12			26·5	9·5		
7000	13			35·75	9·25		
	14			45	9·25		
	15			54·25	9·25	37·25	21·96
	16	7	0	3	8·75		
	17			12·75	9·75		
7500	18			22·25	9·5		
	19			32	9·75	35·75	21·67

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
7700	20	7 0 41·5	9·5			11,000	53	7 6 21	10·75		
	21	51·25	9·75				54	32·5	11·5		
	22	1 0·5	9·25				55	43	10·5		
8000	23	10	9·5	38	21·53		56	54	11	43·75	18·70
	24	20	10				57	7 4·5	10·5		
	25	30·25	10·25			11,500	58	15·5	11		
	26	40·25	10				59	27	11·5		
	27	50·25	10	40·25	20·32		60	38·5	11·5	44·5	18·39
8500	28	2 0	9·75				61	50	11·5		
	29	10	10				62	8 1·25	11·25		
	30	20	10			12,000	63	13	11·75		
	31	30·25	10·25	40	20·45		64	25	12	46·5	17·58
	32	40·25	10				65	37	12		
9000	33	50·25	10				66	48·75	11·75		
	34	3 0·5	10·25				67	9 1	12·25		
	35	10·5	10			12,500	68	13·25	12·25	48·25	16·95
	36	21	10·5	50·75	19·80		69	25·75	12·5		
	37	31	10				70	38·5	12·75		
9500	38	41·25	10·25				71	51·75	13·25		
	39	52	10·75				72	10 4	12·25	50·75	16·12
	40	4 2·5	10·5	41·5	19·71	13,000	73	17	13		
	41	13	10·5				74	30·5	13·5		
	42	23·75	10·75				75	....	13·25		
10,000	43	34·25	10·5				76	57·25	13·5	53·25	15·36
	44	44·75	10·5	42·25	19·36		77	11 11	13·75		
	45	55·5	10·75			13,500	78	24·5	13·5		
	46	5 6	10·5			13,785		12 8			
	47	16·25	10·25			13,915		32·25			
10,500	48	27·5	11·25	42·75	19·13	14,242		13 50·5			
	49	38	10·5			14,498		14 45·5*			
	50	49	11								
	51	6 0	11								
	52	10·25	10·25	42·75	19·13						

A Stiff Breeze down the Plane.

* Stopped.

July 11th, 1839.—Table No. XIII.

Four Second Class Carriages, Nos. 12, 20, 35, 22.

	tons.	cwts.	qrs.
Weight of Carriage and Load . . .	20	0	0
Seven Passengers	0	10	2
	20	10	2

From initial velocity 32·73 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	61	7	11	4			
	60			11	7		
	59			16	5		
	58			23	7		
0	57			29	6	25	32·73
	56			35	6		
	55			41	6		
	54			48	7		
	53			54	6	25	32·73
500	52		12	1	7		
	51			8	7		
	50			14	6		
	49			21	7	27	30·30
	48			26	5		
1000	47			33	7		
	46			40	7		
	45			47	7	26	31·46
	44			53	6		
	43		13	0	7		
1500	42			7	7		
	41			14	7	27	30·30
	40			21	7		
	39			28	7		
	38			34	6		
2000	37			41	7	27	30·30
	36			48	7		
	35			56	8		
	34		14	3	7		
	33			10	7	29	28·21
2500	32			18	8		
	31			26	8		
	30			33	7		
	29			40	7	30	27·27
	28			48	8		
3000	27			56	8		
	26		15	4	8		
	25			11	7	31	26·39
	24			20	9		
	23			28	8		
3500	22			36	8		
	21			44	8	33	24·79

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
3700	20	7	15	52	8		
	19		16	0	8		
	18			8	8		
4000	17			...	9	33	24·79
	16			26	9		
	15			35	9		
	14			44	9		
	13			53	9	36	22·72
4500	12		17	2	9		
	11			11	9		
	10			18	7		
	9			28	10	35	23·37
	8			36	8		
5000	7			45	9		
	6			54	9		
	5		18	3	9	35	23·37
	4			13	10		
	3			22	9		
5500	2			31	9		
	1			40	9	37	22·11
	0			49	9		
	1			58	9		
	2		19	7	9		
6000	3			17	10	37	22·11
	4			27	10		
	5			37	10		
	6			47	10		
	7			57	10	40	20·44
6500	8		20	7	10		
	9			17	10		
	10			27	10		
	11			38	11	41	19·95
	12			50	12		
7000	13		21	1	11		
	14			12	11		
	15			23	11	45	18·18
	16			34	11		
	17			44	10		
7500	18			56	12		
	19		22	8	12	45	18·18

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
7700	20	7 22 20	12			10,200	45	7 27 55	15		
	21	32	12				46	28 10	15		
	22	44	12				47	27	17		
8000	23	56	12	48	17·04	10,500	48	44	17	64	12·79
	24	23 8	12				49	29 1	17		
	25	21	13				50	18	17		
	26	33	12				51	36	18		
	27	45	12	49	16·69		52	53	17	69	11·85
8500	28	58	13			11,000	53	30 10	17		
	29	24 11	13				54	28	18		
	30	24	13				55	48	20		
	31	37	13	52	15·73		56	31 8	20	75	10·91
	32	50	13				57	28	20		
9000	33	25 3	13			11,500	58	50	22		9·29
	34	16	13				59	32 13	23		
	35	29	13				60	36	23		8·89
	36	43	14	66	12·39		61	33 2	26		
	37	57	14				62	27	25	25·5	8·02
9500	38	26 11	14			12,000	63	55	28	...	7·30
	39	25	14				64	34 28	33	...	6·20
	40	40	15	57	14·35		65	35 2	34	...	6·01
	41	55	15				66	38	36	...	5·68
	42	27 10	15				67	36 23	45	...	4·54
10,000	43	25	15			12,500	68	37 30	67	...	3·05
	44	40	15	60	16·63	12,555		39 8		...	*

A Stiff Breeze down the Plane.

* Stopped at 68 Post + 55 yards.

July 12th, 1839.—TABLE No. XIV.

Six Second Class Carriages, Nos. 35, 9, 29, 22, 12, 20.

	tons.	cwts.	qrs.
Weight of Carriages and Load . . .	30	0	0
Six Passengers	0	9	0
Gross weight .	30	9	0

From initial velocity 25·57 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
	61	1 36 53·5					56	1 37 34	8		
	60	37 2	8·5				55	42	8		
	59	10	8				54	50	8		
	58	18·5	8·5				53	58	8	32	25·57
0	57	26	7·5	32·5	25·17						

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
500	52	1 38 6	8			4300	14	1 44 21	12·5		
	51	......	8·5				13	33·5	12·5	49	16·69
	50	23	8·5			4500	12	46·25	12·75		
	49	......	8	33	24·79		11	58·75	12·5		
	48	39	8				10	45 11·75	13		
1000	47	48·25	9·25				9	25	13·25	51·5	15·88
	46	56·5	8·25				8	38	13		
	45	39 5·25	8·75	34·25	23·89	5000	7	52·5	14·5		
	44	14	8·75				6	46 6	13·5		
	43	23	9				5	20·75	14·75	55·75	14·67
1500	42	31·5	8·5				4	36	15·25		
	41	40·25	8·75	35	23·37		3	50·75	14·75		
	40	48·5	8·25			5500	2	47 4·75	14		
	39	58·5	10				1	19·5	14·75	58·75	13·92
	38	40 7·75	9·25				0	34	14·5		
2000	37	16·5	8·75	36·25	22·57		1	48·5	14·5		
	36	25·75	9·25				2	48 3	14·5		
	35	35	9·25			6000	3	19·25	16·25	59·75	13·69
	34	44·25	9·25				4	35	15·75		
	33	53·5	9·25	37	22·11		5	52	17		
2500	32	41 2·5	9				6	49 9	17		
	31	11·25	8·75				7	27·5	18·5	68·25	11·98
	30	21	9·75			6500	8	48	20·5		
	29	30·5	9·5	37	22·11		9	50 9	21		
	28	40·25	9·75				10	30·5	21·5		
3000	27	50·25	10				11	53	22·5	85·5	9·56
	26	42 0·5	10·25				12	51 14·75	21·75		
	25	11·25	10·75	40·75	20·07	7000	13	39	24·25		
	24	22·25	11				14	52 2·5	23·5		
	23	33·5	11·25				15	27·25	24·75	94·25	8·64
3500	22	45	11·5				16	53·5	26·25	....	7·79
	21	56·5	11·5	45·25	18·08		17	53 22·5	29	....	7·05
	20	43 8	11·5			7500	18	56·5	34	....	6·01
	19	19·5	11·5				19	54 37·25	40·75	....	5·02
	18	32	12·5				20	55 25·5	48·25		
4000	17	44·5	12·5	48	17·04	7800	21	56 31·25	65·75		*
	16	56	11·5			7881	...	58 33·5			
	15	44 8·5	12·5								

* Stopped at 21 post + 81 yards.

Breeze from the west, or nearly at right angles to road.

July 12th, 1839.—Table No. XV.

Eight Second Class Carriages.

	tons.	cwts.	qrs.
Weight of Carriages and Load	40	0	0
Six Passengers	0	9	0
Gross weight	40	9	0

From initial velocity 20·07 miles per hour. Down Madeley Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
	61	2	30	58			
	60		31	14	16	......	12·78
	59			27	13	......	15·73
	58			38	11	......	18·59
0	57			48·75	10·75	......	19·02
	56			59	10·25		
	55		32	9	10		
	54			19·25	10·25		
	53			29·5	10·25	40·75	20·07
500	52			40	10·5		
	51			50	10		
	50		33	0	10		
	49			9	9	39·5	20·71
	48			19	10		
1000	47			29·25	10·25		
	46			39	9·75		
	45			49·25	10·25	40·25	20·33
	44			58·5	9·25		
	43		34	8·5	10		
1500	42			18	9·5		
	41			27·75	9·75	38·5	21·25
	40			37·5	9·75		
	39			47·25	9·75		
	38			56·25	9		
2000	37		35	5·5	9·25	37·75	21·67
	36			15·5	10		
	35			25	9·5		
	34			35	10		
	33			44·75	9·75	39·25	20·84
2500	32			54·25	9·5		
	31		36	3·5	9·25		
	30			13·25	9·75		
	29			23	9·75	38·25	21·39
	28			32·75	9·75		
3000	27			42·75	10		
	26			53	10·25		
	25		37	2·5	9·5	39·5	20·71
	24			12·5	10		
	23			22·5	10		
3500	22			33·5	11		
	21			44·25	40·75	41·75	19·59

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
3700	20	2	37	54·5	10·25		
	19		38	5·25	10·75		
	18			16·25	11		
4000	17			27·25	11	43	19·02
	16			38	10·75		
	15			49·75	11·75		
	14		39	0	10·25		
	13			11	11	43·75	18·70
4500	12			22	11		
	11			33	11		
	10			44·25	11·25		
	9			55	10·75	44	18·59
	8		40	6	11		
5000	7			17·5	11·5		
	6			29·25	11·75		
	5			41	11·75	46	17·78
	4			52·75	11·75		
	3		41	4	11·25		
5500	2			......	11·5		
	1			27·25	11·75	46·25	17·69
	0			39	11·75		
	1			50·5	11·5		
	2		42	1·5	11		
6000	3			13·25	11·75	46	17·78
	4			25·75	12·5		
	5			37·75	12		
	6			50·25	12·5		
	7		43	3·25	13	50	16·36
6500	8			16·25	13		
	9			29·5	13·25		
	10			43·5	14		
	11			57	13·5	53·75	15·22
	12		44	10·25	13·25		
7000	13			24·5	14·25		
	14			39	14·5		
	15			53·25	14·25	56·25	14·54
	16		45	7	13·75		
	17			22	15		
7500	18			37	15		
	19			53	16	59·75	13·69

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
7700	20	2	46	8	15		
	21			23·75	15·75		
	22			39·75	16		
8000	23			56	16·25	63	12·98
	24		47	13	17		
	25			30·5	17·5		
	26			48·5	18		
	27		48	6	17·5	70	11·69
8500	28			24·25	18·25		
	29			43·25	19		
	30		49	2·5	19·25		
	31			22·25	19·75	76·25	10·73
	32			42·5	20·25		
9000	33		50	3·5	21		
	34			26	22·5		
	35			48·5	22·5	86·25	9·48
	36		51	11	22·5		
	37			34·75	23·75		

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
9500	38	2	51	58·5	23·75		
	39		52	24	25·5	95·5	
	40			50·75	26·75		
	41		53	15·5	24·75		
	42			43	27·5		
10,000	43		54	7·75	24·75	103·75	
	44			35	27·25		
	45		55	3	28		
	46			32·5	29·5		
	47		56	3	30·5		
10,500	48			35·75	32·75		
	49		57	8	32·25		
	50			42·5	34·5		
	51		58	21	38·5		
	52		59	2	41		
11,000	53			53	51		
11,100	54	3	1	15	82		
11,154			2	42·5			
					*		

Wind from west, but rather less than in preceding.

* Stopped at 54 + 37 yards; the last 600 or 800 yards were in a cutting completely sheltered from the wind.

July 5th, 1839.—TABLE No. XVI.

One Second Class Carriage, No. 17, with Two Side Boards or Wings attached in Front, each projecting 20″.

	tons.	cwts.	qrs.
Weight of Carriage and Load	5	0	0
Five Passengers	0	7	2
Gross weight	5	7	2

From state of rest. Down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	4	32	1			
110	1		33	2	61	......	3·69
220	2			26	24	......	9·37
330	3			46	20	......	11·25
440	4		34	3	17	......	13·23
550	5			19	16	......	14·06
660	6			34	15	......	15·00
770	7			48·5	14·5	......	15·51
880	8		35	2	13·5		
990	9			15·5	13·5	13·5	16·66

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
1100	10	4	35	28·5	13		
1210	11			42	13·5	13·25	16·98
1320	12			54·5	12·5		
1430	13		36	8	13·5	13	17·30
1540	14			19	11		
1650	15			31·5	12·5	11·75	19·15
1760	16		...	... }	12		
1870	17		36	55·5 }	12	12	18·75

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
1980	18	4 37 7·5	12			2640	24				
2090	19	19·5	12	12	18·75	2750	25	4 38 44	17·5	......	12·86
2200	20	32	12·5			2860	26	39 5	21	......	10·71
2310	21	44	12	12·25	18·37	2970	27	32·5	27·5	......	8·18
2420	22	57	13	......	17·30	3080	28	40 13	40·5	......	5·55
2530	23	38 11	14	....	16·07	3139	...	41 11			

Weather fine and dry; rails in good order; breeze from north-west, but scarcely perceptible.

July 5th, 1839.—TABLE No. XVII.

One Second Class Carriage, No. 17. Side boards removed.

	tons.	cwts.	qrs.
Weight of Carriage and Load	5	0	0
Five Passengers	0	7	2
Gross weight	5	7	2

From state of rest. Down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	4 56 0				1760	16	5 0 32·5	11·5		
110	1	57 3·5	63·5	....	3·54	1870	17	43	10·5	11	20·45
220	2	28·5	25	....	9·00	1980	18	54	11		
330	3	48	19·5	....	11·54	2090	19	1 4	10	10·5	21·43
440	4	58 4·25	16·25	....	13·84	2200	20	15	11		
550	5	19	14·75	....	15·25	2310	21	26	11		
660	6	....	14·5	....	15·51	2420	22	37	11	11	20·45
770	7	47	13·5	....	16·66	2530	23	49	12	12	18·75
880	8	59·5	12·5			2640	24	2 1·5	12·5	....	18·00
990	9	59 12	12·5	12·5	18·00	2750	25	16·5	15	....	15·00
1100	10	24	12			2860	26	34	17·5	....	12·86
1210	11	36	12	12	18·75	2970	27	54	20	....	11·25
1320	12	47·5	11·5			3080	28	3 18	24	....	9·37
1430	13	....	11·5	11·5	19·56	3190	29	50·5	32·5	....	6·92
1540	14	5 0 10·5	11·5			3289		5 2			
1650	15	21	10·5	11	20·45						

Weather as in the last.

July 5th, 1839.—Table No. XVIII.

One Second Class Carriage, No. 9, fitted up with pointed end.

	tons.	cwts.	qrs.
Weight of Carriage and Load	5	0	0
Five Passengers	0	7	2
Gross weight	5	7	2

From state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	3 23 0				2090	19	3 28 26	9		
110	1	24 7	67	....	3·36	2200	20	35·25	9·25		
220	2	38	31	....	7·26	2310	21	45	9·75	9·33	24·10
330	3	25 2	24	....	9·37	2420	22	54·25	9·25	....	24·32
440	4	22	20	....	11·25	2530	23	29 4·25	10	....	22·50
550	5	40	18	....	12·50	2640	24	15	10·75		
660	6	56·5	16·5	....	13·63	2750	25	25·25	10·25	10·5	21·43
770	7	26 11·25	14·75	....	15·25	2860	26	37	11·75	....	19·5
880	8	25	13·75	....	16·36	2970	27	50	13		
990	9	38	13			3080	28	30 2·5	12·5	12·75	17·64
1100	10	51	13	13	17·30	3190	29	16·5	14	....	16·07
1210	11	27 2·5	11·5			3300	30	31·5	15	....	15·00
1320	12	14	11·5	11·5	19·56	3410	31	48·5	17	....	13·23
1430	13	....	11			3520	32	31 6·25	17·75	....	12·67
1540	14	36	11	11	20·45	3630	33	28	21·75	....	10·34
1650	15	47·5	11·5			3740	34	53·5	25·5	....	8·82
1760	16	....	10	10·75	20·93	3850	35	32 26·5	33	....	6·81
1870	17	28 6·5	9			3960	36	33 26·5	60	....	3·75
1980	18	17	·10·5	9·75	23·07	3975	...	59			

Weather as in the last.

July 5th, 1839.—Table No. XIX.

One Second Class Carriage, No. 9, with pointed end taken off.

	tons	cwts.	qrs.
Weight of Carriage and Load	5	0	0
Five Passengers	0	7	2
Gross weight	5	7	2

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.	Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s				Yards.		h m s			
0	0	3 58 0				440	4	3 59 52	17	......	13·23
110	1	53	53	......	4·24	550	5	4 0 6	14	......	16·07
220	2	59 16	23	......	9·78	660	6	19·5	13·5	......	16·66
330	3	35	19	......	11·84	770	7	32	12·5		

TABLE (*continued*).

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
880	8	4 0 44	12		
990	9	56	12	12	18·75
1100	10	1 7	11	……	20·45
1210	11	17	10		
1320	12	27·5	10·5	10·25	21·95
1430	13	……………	10·5		
1540	14	48	10	10·25	21·95
1650	15	57·25	9·25		
1760	16	2 7	9·75	9·5	23·68
1870	17	16	9		
1980	18	26	10		
2090	19	35·5	9·5	9·5	23·68
2200	20	45	9·5	……	23·68
2310	21	55	10		
2420	22	………… {	10		
2530	23	3 15	10	10	22·5
Yards.		h m s			
2640	24	4 3 26	11	……	20·45
2750	25	38	12	……	18·75
2860	26	51	13		
2970	27	4 4	13	13	17·30
3080	28	19	15	……	15·00
3190	29	35	16	……	14·06
3300	30	53·5	18·5	……	12·16
3410	31	5 14	20·5	……	10·97
3520	32	38	24	……	9·37
3630	33	6 6	28	……	8·03
3740	34	42	36	……	6·25
3850	35	7 36	54	……	4·16
3905	…	8 59			

Weather as in the last.

TABLE No. XX.

	cwts.	qrs.	lbs.
Fury Engine	147	3	0
Tender	75	0	0
Load	5	0	0
Gross weight . . .	227	3	0

The Fury was reduced as nearly as possible to the condition of a carriage, the connecting rods, pistons, working gear, &c. being detached from the axles, and removed from the engine.

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
0	0	8 11 1			
110	1	59	58	……	3·88
220	2	12 22	23	……	9·78
330	3	40	18	……	12·50
440	4	55	15	……	15·00
550	5	13 9	14	……	16·07
660	6	21·5	12·5		
770	7	34	12·5	12·5	18·00
880	8	44·5	10·5		
990	9	55	10·5	10·5	21·43
Yards.		h m s			
1100	10	8 14 5	10	……	22·50
1200	11	14·5	9·5		
1320	12	24	9·5	9·5	23·68
1430	13	33	9	……	25·00
1540	14	41·5	8·5		
1650	15	50·5	9		
1760	16	58·5	8	8·5	26·47
1870	17	15 7	8·5		
1980	18	15	8	8·25	27·27

TABLE (*continued*).

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
2090	19	8	15	22·25	7·25		
2200	20			30·5	8·25	7·75	29·03
2310	21			38·5	8	......	28·12
2420	22			46·5	8		
2530	23			54·5	8	8	28·12
2640	24		16	3	8·5		
2750	25			11·5	8·5	8·5	26·47
2860	26			21	9·5	......	23·68
2970	27			31	10	......	22·50
3080	28			41·5	10·5	......	21·43
3190	29			52·5	11	......	20·45
3300	30		17	4·5	12·25		
3410	31			16·25	11·75	12·00	18·75
3520	32	8	17	29·75	13·5	......	16·66
3630	33			44·25	14·5	......	15·51
3740	34			59	14·75	......	15·25
3850	35		18	15	16	......	14·06
3960	36			33	18	......	12·50
4070	37			53	20	......	11·25
4180	38		19	13·5	20·5	......	10·97
4290	39			38	24·5	......	9·18
4400	40			20·4	26	......	8·65
4510	41			35·5	31·5	......	7·14
4620	42			21·17	41·5	......	6·14
4710	......			22·38	81		

A Breeze from W.N.W. A drizzling Rain. Rails quite wet, and in good order for Travelling.

TABLE No. XXI.

Two First Class Carriages.

	cwts.	qrs.	lbs.
Caledonian	116	3	0
Earl of Derby	110	0	0
Gross weight . .	226	3	0

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	9	23	0			
110	1			53·25	53·25	......	4·22
220	2		24	15	21·75	......	10·35
330	3			33·5	18·5	......	12·16
440	4			48·75	15·25	......	14·75
550	5		25	2	13·25	......	16·98
660	6			14·25	12·25	......	18·36
770	7			26	11·75	......	19·14
880	8			36·75	10·75		
990	9			47·5	10·75	10·75	20·94
1100	10			57	9·5		
1210	11		26	7	10	9·75	23·08
1320	12			16	9		
1430	13			25	9		
1540	14			34	9	9·00	25·00
1650	15			42·5	8·5		
1760	16			51·25	8·75	8·62	26·00
1870	17			59·25	8		
1980	18		27	7·25	8	8·00	28·12
2090	19			15·75	8·5		
2200	20			23·75	8	8·25	27·26
2310	21	9	27	32	8·25	......	27·26
2420	22			39·75	7·75		
2530	23			48·25	8·5		
2640	24			57	8·75	8·33	27·00
2750	25		28	6·5	9·5		
2860	26			16	9·5	9·5	23·68
2970	27			26·5	10·5	......	21·43
3080	28			37·25	10·75	......	20·94
3190	29			49	11·75	......	19·14
3300	30		29	1	12	......	18·75
3410	31			13·5	12·5	......	18·00
3520	32			27·25	13·75	......	16·36
3630	33			42	14·75	......	15·25
3740	34			58	16	......	14·06
3850	35		30	15·5	17·5	......	12·86
3960	36			35·25	19·75	......	11·39
4070	37			57	21·75	......	10·35
4180	38		31	21·25	24·25	......	9·27
4290	39			50	28·75	......	7·82
4400	40		32	22·5	32·5	......	6·92
4510	41		33	7	44·5	......	5·06
4577	......		34	40	93		

Weather as in the last.

TABLE No. XXII.

Engine, Tender, and four First Class Carriages.

	cwts.	qrs.	lbs.
Fury Tender	222	3	0
Clarence Sovereign Traveller Telegraph	326	3	4
Gross weight	549	2	4

Dist.	Posts.	Times.	Diffs.		Speed.
Yards.		h m s			
0	0	3 30 30			
110	1	31 29	59	......	3·81
220	2	54	25	......	9·00
330	3	32 12	18	......	12·50
440	4	28	16	......	14·06
550	5	42	14	......	16·07
660	6	55	13	......	17·30
770	7	33 7	12	......	18·75
880	8	18	11	......	20·45
990	9				
1100	10	39	21·	10·5	21·43
1210	11	48·5	9·5		
1320	12	58	9·5	9·5	23·68
1430	13	7	9		
1540	14	15·5	8·5	8·75	25·72
1650	15	24	8·5		
1760	16	32·5	8·5	8·50	26·47
1870	17	40·5	8		
1980	18	48·75	8·25	8·12	27·68
2090	19	56	7·25		
2200	20	35 3·5	7·5	7·37	30·50
2310	21	11·25	7·75		
2420	22	19	7·75		
2530	23	26·5	7·5	7·67	29·34
2640	24	34·5	8	8	28·12
Yards.		h m s			
2750	25				
2860	26	3 35 52	17·5	8·75	25·72
2970	27	36 0·5	8·5		
3080	28	9·75	9·25	8·87	25·34
3190	29	19	9·25	......	24·32
3300	30	29·25	10·25	......	21·94
3410	31	40	10·75	......	20·94
3520	32	51·25	11·25		
3630	33	37 2	10·75	11·00	20·45
3740	34	14	12	......	18·75
3850	35	27	13		
3960	36	40	13	13·00	17·30
4070	37	54·5	14·5		
4180	38	38 9	14·5	14·50	15·51
4290	39	25	16	......	14·06
4400	40	42	17	......	13·23
4510	41	39 0·5	18·5	......	12·16
4620	42	20	19·5	......	11·54
4730	43	43	23	......	9·78
4840	44	40 11	28	......	8·04
4950	45	50	39	......	5·78
5060	46	42 11	81	......	2·78
5068	......	39	28		

Weather as in the last.

TABLE No. XXIII.

Six First Class Carriages.

	cwts.	qrs.	lbs.
Express	93	0	24
Herald	91	1	24
Clarence	88	3	24
Sovereign	90	2	24
Traveller	91	2	24
Telegraph	93	1	24
Gross weight	549	2	4

From a state of rest, down Sutton Incline Plane.

Dist.	Posts.	Times.			Diffs.		Speed.
Yards.		h	m	s			
0	0	12	5	30			
110	1		6	26	56	......	4·02
220	2			50	24	......	9·37
330	3		7	8·5	18·5	......	12·16
440	4			25	16·5	......	13·63
550	5			38·5	13·5	......	16·66
660	6			51·5	13	......	17·30
770	7		8	3	11·5	......	19·56
880	8			14	11	......	20·45
990	9			24·25	10·25		
1100	10			34·5	10·25	10·25	21·94
1210	11			44	9·5	......	23·68
1320	12			53	9		
1430	13		9	2	9	9·00	25·00
1540	14			10·25	8·25		
1650	15			19	8·75	8·50	26·47
1760	16			27	8		
1870	17			35	8	8·00	28·12
1980	18			43	8		
2090	19			50·5	7·5	7·75	29·02
2200	20			58	7·5		
2310	21		10	5	7	7·25	31·03
2420	22			13	8		
2530	23			20·25	7·25	7·62	29·5
2640	24	12	10	28·5	8·25		
2750	25			36·5	8	8·12	27·68
2860	26			45·5	9		
2970	27			54·5	9		
3080	28		11	3·5	9	9·00	25·00
3190	29			13	9·5	......	23·68
3300	30			23	10	......	22·50
3410	31			35·5	12·5		
3520	32			44	8·5	10·5	21·43
3630	33			55	11	......	20·45
3740	34		12	7	12	......	18·75
3850	35			20	13	......	17·30
3960	36			33·25	13·25	......	16·98
4070	37			48	14·75	......	15·25
4180	38		13	3	15	......	15·00
4290	39			19·5	16·5	......	13·63
4400	40			38·5	19	......	11·[illegible]
4510	41			59	20·5	......	10·97
4620	42		14	23·5	24·5	......	9·18
4730	43			54·5	31	......	7·26
4840	44		15	51	56·5	......	3·98
4850	...		16	18			

Weather as in the last.

Levels from the top of Sutton Plane to Collins Green.

No. of Post.	Distance.	Fall per 110 yards.	Total fall from 0.	No. of Post.	Distance.	Fall per 110 yards.	Total fall from 0.
		feet.				feet.	
0	0			27	2970	0·48	79·96
1	110	3·61	3·61	28	3080	0·35	80·31
2	220	3·58	7·19	29	3190	0·35	80·66
3	330	3·64	10·83	30	3300	0·30	80·96
4	440	3·65	14·48	31	3410	0·17	81·13
5	550	3·63	18·11	32	3520	0·21	81·34
6	660	3·72	21·83	33	3630	0·18	81·52
7	770	3·59	25·42	34	3740	0·10	81·62
8	880	3·60	29·02	35	3850	0·19	81·81
9	990	3·59	32·61	36	3960	0·13	81·94
10	1100	3·61	36·22	37	4070	0·15	82·09
11	1210	3·60	39·82	38	4180	0·23	82·32
12	1320	3·69	43·51	39	4290	0·26	82·58
13	1430	3·78	47·29	40	4400	0·28	82·86
14	1540	3·64	50·93	41	4510	0·21	83·07
15	1650	3·69	54·62	42	4620	0·14	83·21
16	1760	3·82	58·44	43	4730	0·02	83·23
17	1870	3·75	62·19	44	4840	0·11 Rise.	83·12
18	1980	3·69	65·88	45	4950	0·04 do.	83·08
19	2090	3·86	69·74	46	5060	0·12	83·20
20	2200	3·46	73·20	47	5170	0·30	83·50
21	2310	2·67	75·87	XIII½	5203	0·05	83·55
22	2420	1·30	77·17	XIII $\frac{\mathrm{I}}{\mathrm{II}}$	5643	0·22	83·77
23	2530	1·22	78·39				
24	2640	0·57	78·96	XIII $\frac{\mathrm{III}}{\mathrm{IV}}$	......	0·08	83·85
25	2750	0·36	79·32				
26	2860	0·16	79·48				

July 16th, 1839.

Experiment with the HECLA Locomotive Engine.

On a trip from Liverpool to Birmingham and back with a load consisting of the Tender and Twelve Second Class Grand Junction Carriages. Weather fine and calm; rails dry; water in the Tender warm.

	tons.	cwt.	qrs.	tons.	cwt.	qrs.
HECLA Engine .				12	0	0
Tender	10	0	0			
Carriages, No. 5.	5	0	0			
Do. . 30,	5	0	0			
Do. 29,	5	0	0			
Do. 9,	5	0	0			
Do. 12,	5	0	0			
Do. 20,	5	0	0			
Do. 22,	5	0	0			
Do. 35,	5	0	0			
Do. 31,	5	0	0			
Do. 5,	5	0	0			
Do. 23,	5	0	0			
Do. (open) 7,	5	0	0	70	0	0
Gross weight of Train				82	0	0

Dimensions of the Hecla.

	ft.	in.
Diameter of Driving Wheels	5	0
Diameter of Cylinder	0	$12\frac{1}{2}$
Length of Stroke	0	18
Diameter of Blast-pipe	0	$2\frac{7}{8}$

Internal Dimensions of Firebox.

	ft.	in.
Width crosswise	3	$6\frac{1}{6}$
Lengthwise	2	$4\frac{1}{4}$
Depth from underside of roof to top of Grate Bars	3	$4\frac{1}{2}$
Number of Tubes 117.		
Length of Tubes	8	$6\frac{1}{2}$
External diameter	0	$1\frac{3}{8}$

Heating surface per lineal foot	·375	sq. feet.
Heating surface of Firebox	45·38	do.
Heating surface of Tubes	373·7	do.
Total heating surface	419·08	do.

"Hecla," Tender and Twelve Carriages.

From Liverpool to Birmingham.

Gradient.	Mileposts.	Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.	Gradient.	Mileposts.	Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.
		h m s							h m s				
Fall $\frac{1}{1094}$	1 2	10 28 12					Level	2	10 44 49	66	......	13·63	
	3	29 33	81	......	11·11			3	45 38	49	......	18·37	
	2	30 25	52	......	17·30			9	46 16	38	......	23·68	
	2	31 46	81	......	22·22			1	50	34	......	26·47	
	3	32 23	37	......	24·32			2	47 23	33	......	27·27	
	3	57	34	......	26·47			3	53	30	30·0	30·00	
	1	33 28	31	......	29·03			10	48 24	31			
	2	58	30	......	30·00			1	54	30			
	3	34 26	28	......	32·14		Fall $\frac{1}{89}$	2	49 25	31			
	4	53	27	......	33·33			3	53	28			
	1	35 20	27	......	33·33			11	50 20	27	......	33·33	
	2	46	26	26·00	34·61			1	48	28	......	32·14	Slackened.
	3	36 12	26				Fall $\frac{1}{2762}$	13	55 47	4·59	......	21·07	do. Having overtaken Second Class L. & M. Train.
	5	38	26					2	57 17	1·30	......	20·00	do.
	1	37 3	25					3	58	41	......	21·95	do.
	2	29	26					14	58 35	37	......	24·32	do.
	3	55	26					1	59 13	38	......	23·68	do.
	6	38 21	26				Avg^{e} Fall $\frac{1}{314}$	2	56	43	......	20·93	do.
	1	47	26					19	11 9 26	9·30	......	28·42	
	2	39 14	27					1	54	28	......	32·14	
	3	39	25						10 30				
	7	40 6	27				Rise $\frac{1}{308}$	$\frac{1}{2}$	43 4	......	......	......	Stop. Warrington.
Rise $\frac{1}{96}$	1	37	31	......	29·03			3	44 34	......	......	......	Start.
	2	41 13	36	......	25·00			20	45 35	61	......	14·75	
	3	55	42	......	21·43			1	46 25	50	......	18·00	
	8	42 45	50	......	18·00		Rise	$\frac{1}{2}$ 3	47 48	83	......	21·68	
	1	43 43	58	......	15·56			21	48 25	37	......	24·32	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Rise $\frac{1}{3474}$	1	11	48	58	33	……	27·27	
	3		50	2	64	……	28·12	
	22·1		51	1	59	……	30·51	
	2			30	29	……	31·03	
	3							
	23		52	27	57	……	31·58	
Rise $\frac{1}{310}$	1			56	29	……	31·03	
	2		53	27	31	……	29·03	
	3			58	31	……	29·03	
	24		54	30	32	……	28·12	
	24·2		55	35	65	……	27·70	
Rise $\frac{1}{100}$	3		56	8	33	……	27·27	
	25			45	37	……	24·32	
Rise $\frac{1}{180}$	1		57	27	42	……	21·43	
	2		58	11	44	……	20·45	
	3			54	43	……	20·93	
	26		59	38	44	……	20·45	
Level	1	12	0	20	42	……	21·43	
Fall $\frac{1}{338}$	2			55	35	……	25·71	
	3		1	27	32	……	28·12	
	27			56	29	……	31·03	
	1		2	25	29	……	31·03	
	2		2	51	26	……	34·61	
Level	3		3	18	27	……	33·33	
Rise $\frac{1}{330}$	28			45	27	……	33·33	
	1		4	15	30	……	30·00	
	2			44	29	……	31·03	
	3		5	13	29	……	31·03	
	29			48	35	……	25·71	
	1		6	22	34	……	26·47	
Level	2			55	33	……	27·27	
	3		7	27	32	……	28·12	
	30			58	31	……	29·03	
Rise $\frac{1}{440}$	1		8	28	30	……	30·00	
	2			58	30	……	30·00	
	3		9	28	30	……	30·00	
	31		10	0	32	……	28·12	
Rise $\frac{1}{1383}$	1			32	32	……	28·12	
	2		11	3	31	……	29·03	
	3			41	38	……	23·68	Stop. Hartford.
			12	47	……	……	…….	Start.
Fall $\frac{1}{330}$			16	20				
	32			53				
	1		17	53	60	……	15·00	
	2		18	32	39	……	23·07	
	3		19	6	34	……	26·47	
Level	33			37	31	……	29·03	
	1		20	7	30	……	30·00	
Rise $\frac{1}{400}$	2			37	30	……	30·00	
	3		21	10	33	31	29·03	
	34			39	29			
	1		22	12	33	33	27·27	
	2			45	33			
	3		23	19	34			
	35			51	32			
	1		24	24	33			

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Rise $\frac{1}{2200}$	2	12	24	55	31	……	29·03	
	3		25	26	31	……	29·03	
	36			55	29	……	31·03	
	1		26	25	30	……	30·00	
Rise $\frac{1}{330}$	2			55	30	……	30·00	
	3		27	27	32	……	28·12	
	37		28	0	33	……	27·27	
	1			33	33	……	27·27	
Level	2		29	7	34	……	26·47	
	3			40	33	……	27·27	
	38		30	12	32	……	28·12	
Rise $\frac{1}{440}$	1			43	31	……	29·03	
	2		31	14	31	……	29·03	
	3			43	29	30·5	29·50	
	39		32	15	32			
	1			47	32	……	28·12	
	2		33	19	32	……	28·12	
Level	3			52	33	……	27·27	
	40		34	22	30	……	30·00	
	1			52	30	30	30·00	
	2		35	22	30			
	3			52	30			
	41		36	21	29	29·3	30·71	
	1			50	29			
	2		37	20	30			
	3			50	30			
	42		38	19	29			
	1			49	30			
	2		39	18	29			
	3			47	29			
	43		40	16	29			
	1			45	29			
			42	0	……	……	…….	Stop. Crewe.
			47	30	……	……	…….	Start.
	3		48	12				
Rise $\frac{1}{330}$	44		49	18	66	……	13·63	
	1		50	8	50	……	18·00	
	2			54	46	……	19·56	
	3		51	35	41	……	21·95	
	45		52	15	40	……	22·50	
	1			53	38	……	23·68	
Rise $\frac{1}{263}$	2		53	30	37	……	24·32	
	3		54	6	36	36·18	24·87	
	46			42	36			
	1		55	18	36			
	2			51	33			
	3		56	31	40			
	47		57	8	37			
	1			46	38			
	2		58	22	36			
	3			58	36			
	48		59	33	35			
	1	1	0	8	35			
	2			45	37	36·5	24·66	
	3		1	21	36			
	49			59	38	……	23·68	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Rise $\frac{1}{177}$	1	1	2	37	38	......	23·68	
	2		3	17	40	40·44	22·25	
	3			57	40			
	50		4	38	41			
	1		5	20	42			
	2		6	0	40			
	3			40	40			
	51		7	20	40			
	1		8	1	41			
	2			41	40			
Rise $\frac{1}{330}$	3		9	22	41	......	21·95	
	52		10	0	38	......	23·68	
	1			37	37	......	24·32	
	2		11	14	37	......	24·32	
	3			49	35	......	25·71	
	53		12	24	35	......	25·71	
Level	1			58	34	......	26·47	
	2		13	32	34	......	26·47	
	3		14	7	35	......	25·71	Slacknd.
Fall $\frac{1}{390}$	54		15	1	54	......	16·66	do. Whitmore.
	1			48	47	......	19·15	do.
	2		16	52	64	......	14·06	do.
	3		17	30	38	......	23·68	
	55		18	5	35	......	25·71	
	1			36	31	......	29·03	
	2		19	6	30	......	30·00	
	3			33	27	27	33·83	
	56		20	1	28			
	1			27	26			
	2			54	27			
Fall $\frac{1}{390}$	3		21	20	26	......	34·61	
	57			46	26	......	34·61	
	1		22	13	27	27·14	33·16	
	2			40	27			
	3		23	7	27			
	58			35	28			
	1		24	2	27			
	2			30	28			
	3			56	26			
Fall $\frac{1}{650}$	59		25	23	27	27·62	32·58	
	1			49	26			
	2		26	17	28			
	3			43	26			
	60		27	11	28			
	1			38	27			
	2		28	8	30			
	3			37	29			
	61		29	5	28	28·70	31·36	
Fall $\frac{1}{303}$	1			33	28			
	2		30	2	29			
	3			30	28			
	62			59	29			Sm. low.
	1		31	27	28			Bd.coke.
	2			55	28			
	3		32	23	28			
	63			51	28			
	1		33	19	28			

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Fall $\frac{1}{303}$	2	1	33	47	28	28·70	31·36	
	3		34	16	29			
	64			44	28			
	1		35	14	30			
	2			43	29			
	3		36	13	30			
	65			42	29			
	1		37	12	30			
	2			41	29			
	3		38	11	30			
Fall $\frac{1}{2103}$	66			40	29	......	31·03	
	1		39	12	32	......	28·12	
	2			45	33	......	27·27	
	3		40	18	33	......	27·27	
	67			53	35	......	25·71	
	2		42	7	1·14	......	24·32	
	3			42	35	......	25·71	
	68		43	21	39	......	23·07	
			44	30	......	......	....	Stopped.
Rise $\frac{1}{636}$			51	5	......	......	....	Started.
	2		52	31				
	3		53	27	56	......	16·07	
	69		54	16	49	......	18·37	
	1			58	42	......	21·43	
	2		55	36	38	......	23·68	
Level	3		56	15	39	......	23·07	
	70			50	35	......	25·71	
	1		57	23	33	......	27·27	
Rise $\frac{1}{400}$	2			54	31	......	29·03	
	3		58	27	33	......	27·27	
	71		59	0	33	......	27·27	
	1			34	34	34	26·47	
	2	2	0	8	34			
	3			41	33			
	72		1	15	34			
	1			50	35			
	2		2	23	33	33·5	26·87	
Level	3			57	34			
	73·1		4	1	64	......	28·12	
	2			30	29	......	31·03	
	3		5	0	30	......	30·00	
Rise $\frac{1}{440}$	74			30	30	......	30·00	
	1		6	2	32	......	28·12	
	2			36	34	32·5	27·70	
	3		7	7	31			
	75			39	32	......	28·12	
	1		8	12	33	......	27·27	
	2			45	33	......	27·27	
	3		9	20	35	......	25·71	
Rise $\frac{1}{330}$	76			55	35	......	25·71	
	1		10	30	35	35·36	25·45	
	2		11	5	35			
	3			38	33			
	77		12	12	34			
	1			47	35			
	2		13	22	35			
	3			57	35			

TABLE (*continued*).

Gradient.	Mileposts.	Times. h	m	s	Differences.	Differences averaged.	Miles per hour.	Remarks.
Rise $\frac{1}{330}$	78	2	14	31	34	35·36	25·45	
	1		15	8	37			
	2			43	35			
	3		16	21	38			
	79			57	36			
	1		17	34	37			
	2		18	11	37			
	3			47	36			
	80		19	23	36			
	1		20	0	37			
	2							
	3		21	10				
	81			45	35			
	1		22	20	35			
	2			53	33			
	3		23	27	34			
	82		24	3	36			
	1			38	35			
	2		25	14	36			
	3			49	35			
	83		26	25	36			
			27	30		......	......	Stop. Wolverhampton.
			31	42		......	......	Start.
	2		32	59				
Level	3		33	46	47	......	19·15	
	84		34	25	39	......	23·07	
Fall $\frac{1}{330}$	1			58	33	......	27·27	
	2		35	28	30	......	30·00	
	3			57	29	......	31·03	
	85		36	25	28	......	32·14	
	1			52	27	......	33·33	
	2		37	17	25	26	34·61	
	3			44	27			
	86		38	8	24	24·50	36·73	
	1			32	24			
	2			57	25			
	3		39	22	25			
	87			47	25			
	1		40	11	24			
Fall $\frac{1}{332}$	2	2	40	37	26	......	34·61	
	3		41	3	26	......	34·61	
	88			30	27	27	33·33	
	1			57	27			
	2		42	24	27			
	3			51	27			
	89		43	18	27			
	1			45	27			
	2		44	13	28			
	3			39	26			
	90		45	6	27			
	1			33	27			
	2		46	0	27			
	3			28	28			
	91			54	26			
	1		47	20	26	25·35	35·48	
	2			47	27			
	3		48	11	24			
	92			37	26			
	1		49	3	26			
	3			54	51			
	93		50	19	25			
	1			43	24			
	2		51	8	25			
Level	3			33	25			
	94			58	25	......	36·00	
	1		52	23	25	......	36·00	
	2			48	25	......	36·00	
Rise $\frac{1}{367}$	3		53	15	27	......	33·33	
	95			42	27	......	33·33	
	1		54	12	30	......	30·00	
	2			42	30	......	30·00	
	3		55	14	32	......	28·12	
	96			46	32	......	28·12	
	1		56	20	34	......	26·47	
			57	10	......	......	......	Stop. Vauxhall Station, Birmingham.

CONSUMPTION OF COKE.

616 pounds used to get up steam in the morning, and to fill up the firebox previous to starting.	To be added in the second trip.
Quantity of coke consumed during the trip of 95 miles, *inclusive* of what was required to fill up the firebox at the end of the journey	3654 lbs.
Coke consumed per mile	38·4 lbs.
Ditto per ton per mile upon the load (nett)	·55lbs.

CONSUMPTION OF WATER.

Intervals.	Dist. in miles.		Water evaporated.	Water evaporated. Per mile.	Water evaporated. Per hour.	
			Gallons.	Gallons.	Cubic feet.	
From Liverpool to Warrington...	18	......	393	21·83		337 cubic ft. water evaporated by 3654 lbs. coke = 1 cub. ft. water per 10·84 lbs. coke.
Warrington to Crewe	24	......	555	23·12		
Crewe to Stafford............	24¾	......	519	20·97		
Stafford to Whampton......	14¾	......	396	26·84		
Whampton to Birmingham	13	......	245	18·15		
	95		2108	22·19	93·2	

Statement of the time occupied in performing the trip from Liverpool to Birmingham, 95 miles, on an average rise of 1 in 2462, and of the time lost in stoppages and slackening and getting into the speed at the Stations.

	h	m	s		h	m	s
Started from Liverpool........................	10	28	12	inclusive of stoppages	4	28	58
Arrived in Birmingham.........................	2	57	10				

TIME LOST ON THE ROAD.	m	s	Lost. m	Lost. s	h	m	s
Getting up speed at Liverpool, 1½ to 4 miles, = 2½ miles.........	6	41					
At full speed would have been..	4	20	2	21			
Slackened speed at Sutton, &c. 11¼ to 14½ miles, = 3¼ miles ...	9	8					
At full speed	5	51	3	17			
Stoppage, &c. at Warrington, 19¼ to 21¼ miles, = 2 miles	39	4					
At full speed	4	16	34	48			
Stoppage, &c. at Hartford, 31½ to 33½ miles, = 2 miles...........	9	34					
At full speed	4	0	5	34			
Stoppage, &c. at Crewe, 43¼ to 45¼ miles, = 2 miles	12	8					
At full speed	4	56	7	12			
Slackened at Whitmore, 53½ to 55½ miles, = 2 miles...............	5	34					
At full speed	4	0	1	34			
Stoppage, &c. at Stafford, 67¾ to 69¾ miles, = 2 miles...........	13	33					
At full speed	5	4	8	29			
Stoppage, &c. at Whampton, 83 to 85 miles, = 2 miles............	10	0					
At full speed	4	0	6	0			
Slackened at Birmingham, 96 to 96½ miles, = ½ mile	1	24					
At full speed	1	0		24	1	9	39
Time which would have been occupied if the Train had started from Liverpool at full speed, and travelled from thence to Birmingham without stopping..					3	19	19

Equal to an average speed of 28·60 miles per hour.
Up an average rise of 1 in 2462.
Time, exclusive of *dead stoppages*, 3 hours 37 minutes.

"Hecla," Tender and Twelve Carriages.

From Birmingham to Liverpool.

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Fall $\frac{1}{567}$		4	47	30				
	1		49	27				
	1		50	19	52	......	17·30	
	2			58	39	......	23·07	
	3		51	32	34	......	26·47	
	2		52	4	32	......	28·12	
	1			33	29	......	31·03	
	2		53	0	27	27·5	32·73	
	3			28	28			
Level	3			55	27	27·5	32·73	
	1		54	23	28			
	2			51	28	......	32·14	
Rise $\frac{1}{332}$	3		55	20	29	......	31·03	
	4			50	30	......	30·00	
	1		56	21	31	......	29·03	
	2			53	32	......	28·12	
	3		57	25	32	......	28·12	
	5			57	32	......	28·12	
	1		58	30	33	32·9	27·85	
	2		59	2	32			
	3			32	30			
	6	5	0	6	34			
	1			39	33			
	2		1	13	34			
	3			47	34			
	7		2	20	33			
	1			53	33			
	2		3	25	32			
	3			58	33			
	8		4	30	32			
	1		5	3	33			
	2			35	32			
	3		6	9	34			
	9			42	33			
	1		7	16	34			
	2			49	33			
	3		8	22	33			
	10			55	33			
Rise $\frac{1}{330}$	1		9	28	33	33	27·27	
	2		10	1	33			
	3			34	33			
	11		11	10	36	35·9	25·07	
	1			46	36			
	2		12	22	36			
	3			57	35			
	12		13	33	36			
	1		14	10	37			
	2			45	35			
	3		15	22	37			
	13			58	36			
	1		16	33	35			
Level	2		17	7	34	......	26·47	
	3			39	32	......	28·12	
	14	5	18	20	41	......	21·95	Wolverhampton.
	1			55	35	......	25·71	
			22	8	...	......	......	Stop.
			23	12	...	......	......	Start.
	2		24	3				
Fall $\frac{1}{330}$	3			43	40	......	22·50	
	15		25	19	36	......	25·00	
	1			52	33	......	27·27	
	2		26	22	30	......	30·00	
	3			50	28	......	32·14	
	16 1		27	41	51	......	35·30	
	2		28	7	26	......	34·61	
	3			33	26	24·5	36·75	
	17			56	23			
	1		29	20	24	24·05	37·41	
	2			44	24			
	3		30	8	24			
	18			32	24			
	1			56	24			
	2		31	19	23			
	3			45	26			
	19		32	8	23			
	1			32	24			
	2			56	24			
	3		33	20	24			
	20			44	24			
	1		34	9	25			
	2			32	23			
	3			56	24			
	21		35	19	23			
	1			44	25			
	2		36	9	25			
Fall $\frac{1}{440}$	3			33	24	24·5	36·75	
	22			58	25			
	1		37	23	25	24·5	36·75	
	2			47	24			
	3		38	12	25	25·25	35·64	
	23			38	26			
	1		39	4	26			
	2			28	24			
Level	3			54	26	......	34·61	
	24		40	20	26	......	34·61	
	1			48	28	26·5	33·97	
	2		41	13	25			
	3			38	25	26·5	33·97	
Fall $\frac{1}{400}$	25		42	6	28			
	1			32	26	......	34·61	
	2			57	25	......	36·00	
	3		43	21	24	24·5	36·75	
	26			46	25			
	1		44	10	24	24·5	36·75	
	2			35	25			
	27		45	23	48	......	37·50	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Level	1	5	45	48	45	......	36·00	
	2		46	14	26	......	34·61	
Fall $\frac{1}{656}$	3			40	26	......	34·61	
	28		47	7	27	26·5	33·97	
	1			33	26			
	2		48	1	28	......	32·14	
	3			31	30	......	30·00	
			49	35	...	......	......	Stop. Stafford.
			52	0	...	......	......	Start.
	29 1		54	1				
Rise $\frac{1}{2103}$	2			59	58	......	15·51	
	3		55	44	45	......	20·00	
	30		56	24	40	......	22·50	
	1		57	6	42	......	21·48	
	2			42	36	......	25·00	
	3		58	17	35	.....	25·71	
	31			50	33	......	27·27	
	1		59	22	32	......	28·12	
	2			53	31	31	29·03	
Rise $\frac{1}{303}$	3	6	0	24	31			
	32			55	31			
	2		1	57	62	......	29·03	
	3		2	27	30	31	29·03	
	33			59	32			
	1		3	30	31	31·3	28·75	
	2		4	1	31			
	3			33	32			
	34		5	4	31			
	1			34	30			
	2		6	6	32			
	3			37	31			
	35		7	9	32			
	1			40	31			
	2		8	12	32			
	3			43	31			
	36		9	15	32			
	1			46	31			
Rise $\frac{1}{630}$	2		10	17	31	31	29·03	
	3			48	31			
	37		11	19	31			
	1			51	32	31·5	28·56	
	2		12	22	31			
	3			53	31	31	29·03	
	38		13	24	31			
	1			55	31			
	2		14	26	31			
Rise 390	3			58	32	......	28·12	
	39		15	30	32	......	28·12	
	1		16	3	33	33	27·27	
	2			35	32			
	3		17	9	34			
	40			42	33			
	1		18	15	33			
	2			48	33			
Rise $\frac{1}{390}$	3		19	21	33	33	27·27	
	41			54	33			
		h	m	s				
Rise $\frac{1}{390}$	1	6	20	28	34	34	26·47	
	2		21	2	34			
	3			36	34	34·25	26·28	
	42		22	12	36			
	1			45	33			
	2		23	19	34			
	3			54	35	......	25·71	
	43		24	51	57			
			25	5	...	......	......	Stop. Whitmore.
			27	52	...	......	......	Start.
	1		29	44				
	2		30	44	60	......	15·00	
Level	44		32	9	85	......	21·16	
Fall $\frac{1}{330}$	1			43	34	......	26·47	
	2		33	14	31	......	29·03	
	3			44	30	......	30·00	
	45		34	12	28	......	32·14	
	1			38	26	......	34·61	
	2		35	5	27	......	33·33	
	3			31	26	......	34·61	
Fall $\frac{1}{177}$	46			56	25	......	36·00	
	1		36	20	24	......	37·50	
	2			43	23	......	39·13	
	3		37	6	23	......	39·13	
	47			28	22	21.77	41·32	
	1			50	22			
	2		38	13	23			
	3			35	22			
	48			56	21			
	1		39	18	22			
	2			39	21			
	3		40	1	22			
	49			22	21			
	1			44	22	......	40·91	
Fall $\frac{1}{263}$	2		41	7	23			
	3			31	24			
	50			54	23	23	39·13	
	1		42	16	22			
	2			39	23			
	3		43	4	25			
	51			25	21			
	1			47	22	23	39·13	
	2		44	10	23			
	3			33	23			
	52			56	23			
Fall $\frac{1}{330}$	1		45	20	24			
	2			43	23			
	3		46	7	24	24	37·50	
	53			31	24			
	1		47	1	30	......	30·00	
	2			45	44	......	20·45	
Level			48	20	...	......	......	Stop. Crewe.
			51	45	...	......	......	Start.
	54		53	55				
	1		54	40	45	......	20·00	
	2		55	19	39	......	23·07	
	3			53	34	......	26·47	

TABLE (*continued*).

Gradient.	Mileposts.	Times.			Differences.	Differences averaged.	Miles per hour.	Remarks.
		h	m	s				
Level	55	6	56	26	33	......	27·27	
	1			57	31	......	29·03	
	2		57	26	29	28·89	31·15	
	3			55	29			
	56		58	24	29			
	1			53	29			
	2		59	22	29			
	57	7	0	20	58			
	1			48	28			
	2		1	17	29			
Fall $\frac{1}{440}$	3			45	28	......	32·14	
	58		2	13	28	......	32·14	
	1			40	27	......	33·33	
	2		3	7	27	......	33·33	
	3			32	25	......	36·00	
Level	59			58	26	......	34·61	
	1		4	26	28	28	32·14	
	2			54	28			
	3		5	22	28			
	60			50	28			
Fall $\frac{1}{330}$	1		6	17	27	......	33·33	
	3		7	10	53	......	33·97	
	61			36	26	......	34·61	
Fall $\frac{1}{2200}$	1		8	0	24	25·5	35·30	
	2			27	27			
	3			53	26	......	34·61	
	62		9	21	28	......	32·14	
Fall $\frac{1}{400}$	1			48	27	......	33·33	
	2		10	14	26	26·43	34·05	
	3			40	26			
	63		11	7	27			
	1			33	26			
	3		12	26	53			
	64			53	27			
Level	1		13	19	26	......	34·61	
Fall $\frac{1}{330}$	2			46	27	......	33·33	
	3		14	16	30	......	30·00	
	65			48	32	......	28·12	
	1		15	20	32	34	26·47	
Fall $\frac{1}{1585}$	2			56	36			
	3		16	34	38	37	24·32	
	66		17	10	36			
Fall $\frac{1}{440}$	1			43	33	......	27·27	
	2		18	15	32	......	28·12	
	3			45	30	......	30·00	
	67		19	14	29	......	31·03	
Level	1			42	28	......	32·14	
	2		20	11	29	29	31·03	
	3			39	28			
	68		21	9	30			
Fall $\frac{1}{330}$	1			38	29	......	31·03	
	2		22	5	27	27·5	32·73	
	3			33	28			
	69		23	0	27	......	33·33	
	1			26	26	......	34·61	
Level	3		24	17	51	......	35·30	
Rise $\frac{1}{338}$	70	7	24	44	27	......	33·33	
	1		25	14	30	30·5	29·51	
	2			45	31			
	3		26	19	34	......	26·47	
Level	71			53	34	......	26·47	
	1		27	27	34	......	26·47	
Fall $\frac{1}{180}$	2		28	0	33	......	27·27	
	3			32	32	......	28·12	
	72		29	2	30	30·5	29·51	
	1			33	31			
Fall $\frac{1}{100}$	2		30	0	27	......	33·33	
Fall $\frac{1}{310}$	3			25	25	......	36·00	
	73 1		31	20	55	25·25	35·64	
	3		32	6	46			
	74			31	25	25·5	35·30	
	1			57	26			
Fall $\frac{1}{3474}$	2		33	24	27	27·44	32·79	
	3			52	28			
	75		34	19	27			
	2		35	14	55			
	76		36	9	55			
	1			37	28			
	2		37	4	27			
Fall $\frac{1}{308}$	77			59	55	27·66	32·58	
	1		38	27	28			
	2			59	32	......	28·12	
			40	30	...	......	......	Stop. Warrington.
Rise $\frac{1}{400}$					...	......	......	Start.
	78	8	4	45				
	1		5	38	53			
Rise $\frac{1}{3300}$	2		6	36	58	......	15·51	
Fall $\frac{1}{711}$	3		7	35	59	......	15·26	
	79		8	13	38	......	23·68	
	1			43	30	......	30·00	
	2		9	13	30	31	29·03	
	3			45	32			
Rise $\frac{1}{626}$	80		10	16	31			
	1			48	32	......	28·12	
	2		11	22	34	33	27·27	
	3			54	32			
	81		12	30	36	......	25·00	
	82 3		16	49	4·19	......	24·32	
	83		17	30	41	......	21·95	
XIV.	1		18	8	38	......	23·68	
	2			42	34	......	26·47	
	3		19	15	33	......	27·27	
	84		19	46	31	......	29·03	
Rise XIII = $\frac{1}{2762}$	1		20	16	30	......	30·00	
	2			46	30	......	30·00	
	3		21	15	29	......	31·03	
	85			43	28	......	32·14	
XII.	1		22	12	29	......	31·03	
	2			41	29	......	31·03	

TABLE (*continued*).

Gradient.	Mileposts.	Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.	Gradient.	Mileposts.	Times.	Differences.	Differences averaged.	Miles per hour.	Remarks.
		h. m. s.							h m s				
Rise XI $\frac{1}{89}$	3	8 23 12	31	......	29·03		Level IX	3	8 30 50	43	......	20·93	*
	86	47	35	......	25·71			88	31 28	38	......	23·68	
	1	24 33	46	......	19·56			1	32 5	37	......	24·32	
	2	25 27	54	......	16·66		VI Rise $\frac{1}{1094}$ $1\frac{1}{11}$	91	39 58	7·53	......	20·93	
	3	26 32	65	......	13·84			1	40 30	32	......	28·12	
	87	28 1	89	......	10·11	Slipping.		2	41 0	30	......	30· 0	
X Level	1	29 17	76	......	11·84	*		95¾	51 0	10·0	......	25· 5	Stopped.
	2	30 7	50	......	18·00								

* Interrupted by overtaking Liverpool and Manchester Train.

CONSUMPTION OF COKE.

	lbs.
Used during the trip of 95 miles, exclusive of what would have been required to fill up the firebox at the end of the journey	2790·
Add the quantity of coke at first put in to get up steam and fill the firebox	616·
	3406·
Coke consumed per mile	35·8
Coke consumed per ton per mile	·51

CONSUMPTION OF WATER.

Intervals.	Miles.		Water evaporated.	Water evaporated.		
				Per mile.	Per hour.	
			Gallons.	Gallons.	Cubic feet.	
From Birmingham to Wolverhampton	13¼	Rise.	311	23·04		300 cubic feet of water evaporated by 3406 lbs. of coke. = 1 cubic foot of water by 11·35 lbs. of coke.
Wolverhampton to Stafford	14¾	Fall.	244	16·54		
Stafford to Crewe............	24¾	Rise & Fall.	452	18·26		
Crewe to Warrington	24	Fall.	439	18·29		
Warrington to Liverpool...	18	....	427	23·72		
Total	95	....	1873	19·71	85·7	

Statement of the time occupied in performing the trip from Birmingham to Liverpool, 95 miles, down an average descent of 1 in 2462, and of the time lost in stoppages, and slackening and getting into speed at the Stations.

	h m s		h m s
Started from Birmingham	4 47 30	inclusive of stoppages.	4 3 30
Arrived in Liverpool	8 51 0		
TIME LOST ON THE ROAD.	m s	m s	
Getting up speed at Birmingham, ¾ to 2¾ miles, = 2 miles	5 58		
At full speed would have been	3 40	2 18	
Stoppage at Wolverhampton, 13¾ to 15¾ miles, = 2 miles	9 11		
At full speed	4 0	5 11	
Stoppage, &c. at Stafford, 28½ to 31½ miles, = 3 miles	11 52		
At full speed	6 0	5 52	
Stoppage, &c. at Whitmore, 42½ to 44½ miles, = 2 miles	9 55		
At full speed	4 16	5 39	
Stoppage, &c. at Crewe, 53 to 55½ miles, = 2½ miles	10 55		
At full speed	4 20	6 35	
Stoppage, &c. at Warrington, 77½ to 79½ miles, = 2 miles	30 16		
At full speed	4 0	26 16	
Delay arising from overtaking Train on Liverpool and Manchester Line, 87¾ to 95¾ miles, = 8 miles	20 10		
At full speed	16 0	4 10	56 1
Time which would have been occupied if the Train had started from Birmingham at full speed, and travelled from thence to Liverpool without stopping			3 7 29

Equal to an average speed of 30·40 miles per hour.
On an average descent of 1 in 2462.
Time, exclusive of *dead stoppages*, 3 hours and 30 minutes.

TABLE of the uniform speeds attained by the "HECLA," with a load consisting of the Tender and Twelve Carriages (= 70 tons, gross) on the several Gradients of the Grand Junction Railway.

Gradient.	Uniform Speed.		Mean.	Remarks.
	Liverpool to Birmingham.	Birmingham to Liverpool.		
	Miles per hour.	Miles per hour.	Miles per hour.	
Rise, 1 in 96	13·63			
1 in 177	22·25	....	22·25	
1 in 265	24·87	....	24·87	
1 in 330	25·45	25·07	25·26	
1 in 390	....	26·28	26·28	
1 in 400	26·47			

TABLE (*continued*).

Gradient.	Uniform Speed.		Mean.	Remarks.
	Liverpool to Birmingham.	Birmingham to Liverpool.		
	Miles per hour.	Miles per hour.	Miles per hour.	
Rise, 1 in 400	27·27	....	26·87	
1 in 505	....	28·75	28·75	
1 in 532	....	27·35	27·35	
1 in 590	....	27·27	27·27	
1 in 650	....	29·08	29·08	
Level	30·71	31·15	30·93	
Fall, 1 in 3474	....	32·79	32·79	First starting, and in better than average order.
1 in 1094	34·61	....	....	
1 in 650	32·58	....	32·58	
1 in 590	33·16	....	33·16	
1 in 532	34·30	....	34·30	
1 in 505	31·36	....	....	Bad coke.
1 in 440	....	35·64	35·64	
1 in 400	....	36·75	36·75	
1 in 330	36·73	37·41	37·07	
1 in 265	....	39·13	39·13	
1 in 177	....	41·32	41·32	

"HECLA" Tender and Twelve Carriages.

Liverpool to Birmingham,	95 miles,	3654 lbs. of coke,	2108 gallons of water.
Birmingham to Liverpool,	95 miles,	3406 lbs. of coke,	1873 gallons of water.
	190 miles,	7060 lbs. of coke,	3981 gallons of water.

Coke per mile .... 37·16 lbs.
Water per mile .... 37·16 imperial gallons.

One pound of coke evaporates 5·63 lbs. of water.

It is to be observed that the previous statement comprises the entire quantity of coke supplied to the engine, both for getting up the steam in the morning, and for work during the day; whereas, on the other hand, the water recorded was that actually used during the two *journeys*.

The duty of 1 lb. of coke is greater than is here assigned.

Report of a Committee appointed at the Tenth Meeting of the Association, on the Construction of a Constant Indicator for Steam-Engines. Members of the Committee, the Rev. Professor MOSELEY, *M.A., F.R.S.*, EATON HODGKINSON, *Esq., F.R.S.*, J. ENYS, *Esq.*

A REGISTRATION of the work done by a steam-engine made at its piston, or of the work done by the steam upon the piston, appears to offer important practical advantages, as compared with any other method of registration, in these respects; that it is applicable to every possible variety in the circumstances under which the engine is made to operate, and that it is a registration of the work of the engine *absolutely*, and separated from all those uncertain influences of friction, or other prejudicial resistances which intervene between the piston and the working points of the machine to which it gives motion; influences which it is impossible to eliminate from a registration of the work done at the working points, with certainty or accuracy.

In proof of the advantages which would result from any method of registration of the *work*, and therefore of the *duty* of steam-engines, could it be made to assume this general character, it is sufficient to point to the history of the Cornish pumping-engines. It is entirely from the registration of their work (so easily made in respect to them by reason of the simple and constant nature of that work), that has resulted that admirable knowledge of the working properties of the steam-engine, which is so extensively diffused through the mining districts; and to the same cause is entirely due (as a consequence of this knowledge), that vast economy of power and fuel in the working of the Cornish engines, which has so recently been brought under the consideration of the Association.

If a method of registration equally (or even yet *more*) certain and easy of application could be extended to the working of *all* engines, no matter how varied or how complicated, or how intermittent the nature of their operations might be—to the engines, for instance, which perform the varied and intermittent labours of an engineer's workshop or a manufactory, or to the engine of a steam-boat—giving by a method beyond the control or interference of the engineer, the *work* of the engine of such a boat during any given time—a day, a week, or a month,—and the *duty* which the engine does with each bushel of coals, independently of her speed through the water, and of all considerations dependent upon the *form* of the boat, or the direction or force of the *winds* or *currents*, or of the *tides*—it would at once become possible, by recording and publishing the duty of each engine periodically, to introduce precisely that competition of economy in power between the engineers in factories and the engineers in steam-boats, which has been attended with results of such advantage to the mining districts of Cornwall.

If, again, we conceive the work of each of the engines of a *railway company* to be made thus to register itself, and the amount thus registered to be published under the form of a weekly or a monthly return, together with the quantity of the coals consumed by each, it is evident that a competition amongst the engineers would be the immediate result, and a consequent economy to the company in the use of the fuel. A competition which would probably lead to that scientific adjustment of the amount of the load to the evaporating power of the engine and the speed of transit, which adjustment is the true and the great secret of the economical working of a line of railway. Passing over the use which the resident engineer of such a line of railway might make of an indicator like this, to determine the condition of the rails, and the general working state of any portion of the line, by throwing the indicator of a trial engine into gear at any such portion of the line, and thus registering the amount of work necessary to carry the engine over that particular portion of the line; passing too over the value of the purely scientific data which would result from the extensive accumulation of records such as these, the Committee are desirous more particularly to point out the importance of the knowledge it might supply, not only as to the economical *working* of marine engines, but as to their construction, and the build or construction of steam-boats. In the existing state of our knowledge, it is impossible to divide with certainty between the builder of the boat and the builder of its engine, the responsibility which belongs to their several parts in giving speed to it. A registration such as that here spoken of would, however, at once make this division. It would determine the merits of the engine independently of the properties of the boat, and the properties of the boat separately from the merits of the engine.

There are other points of view in which the value of such a method of registration, if by any means it might be attained, is perhaps equally apparent; enough, however, has been said to justify the Association in appointing a committee to inquire into the possibility of effecting such a registration, and placing at their disposal a grant of 100*l.* to cover the expense of such trials as they might recommend to be made.

WATT'S INDICATOR.

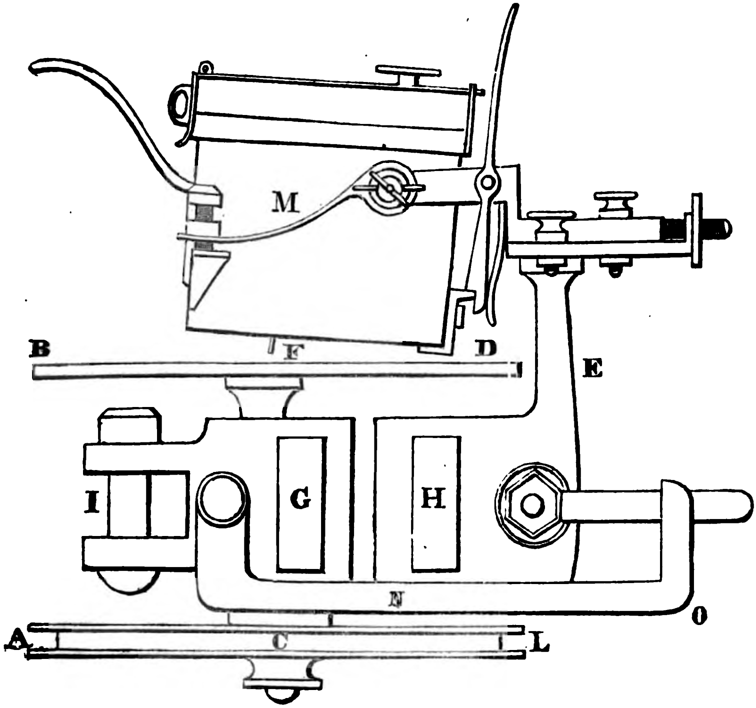
The only instrument at present used for determining the work done by the steam on the piston of an engine, is that well known as the indicator of Watt. Its insufficiency for the purpose of a registration, such as that the Committee proposed to themselves, was at once apparent to them. It determines the work only at a *single stroke* of the engine; the desideratum was a registration of the work continued to any number of strokes, and under such variations of the resistance as should render the work done at any one stroke no correct representative of the work done at any other. The indicator of Watt presents its registration of the work thus done at a single stroke, under the form of a certain small area, bounded by a curved line, which is traced by a pencil fixed to a small piston sustaining the pressure of steam from the cylinder of the engine, and made by means of a spiral spring to deviate from its position of repose by spaces which are directly proportional to the pressures sustained; the paper which receives the trace of the pencil receiving meanwhile a *lateral* motion, constantly proportional to the motion of the piston itself.

Were it not that the first objection, the want of *continuity*, was fatal to this method of registration for the object proposed to the consideration of the Committee, the great *inaccuracies* to which it is liable in the mechanical tracing of the curve, and the geometrical determination of the area it bounds, would have led them to seek for some more certain method of registration, and one more easy of application, to place in the hands of the working engineer.

The labours of the Committee were with this view specially directed to the application of a principle of dynamometrical admeasurement, first proposed by M. Poncelet, the illustrious President of the Institute, described by him in his work, entitled 'Mécanique Industrielle,' and in the work of M. Morin, 'Déscription d'Appareils Dynamometriques' (published at Metz in 1838).

MORIN'S COMPTEUR.

This principle will be best understood by the example of an application which M. Morin has made of it, to the construction of an instrument for registering the work done by a team of horses dragging a loaded carriage at any given velocity over any length of road.



I G N O and E H K in the figure represent two separate pieces, which may be made to move upon one another in the directions H K and G I. Two springs shackled together at their extremities, and represented in a subsequent figure, are severally inserted in the apertures G and H, and fixed there by their middle points.

The separation of the two in the direction G I and H K, supposes therefore a deflection of these springs. The piece G I is connected with the carriage to be moved by means of the bolt I, and to the piece E H K the horses are attached by means of the shank K. Thus the pressure of traction is transmitted from the horses to the carriage *through* the system of springs, and by the well-known property of elastic bodies a separation is thus produced in these springs, which (so long as it does not exceed a certain limit) is always directly proportioned to the amount of this pressure. B D represents a flat circular disc, and A L a pulley or sheave, both fixed upon the same vertical axis F C. The sheave A L receives its motion by means of a band from a sheave revolving with the wheel of the carriage, so that the motion of the circumference of A L bears always a constant ratio to the space traversed by the carriage. To the piece E H K is attached (by means of a joint or hinge) the box M, containing certain mechanism intended to register the number of revolutions made by a certain wheel.

This wheel is represented at F; it rests by its edge upon the disc, its plane is at right angles to the line of traction; and its position on the box is such, that when the carriage sustains no traction, and the springs suffer therefore no deflection, it rests over the centre of the revolving disc B D.

In this position of the wheel F it would evidently receive no motion from the revolution of the disc B D, however fast that disc might revolve, whilst in any other position between F and D, the wheel F would receive a motion from the revolution of the disc, which motion (if the revolution of the disc were *uniform*) would be directly proportioned to the distance of the wheel F from the centre of the disc, that is, directly proportioned to the separation of the springs, or to the force of the traction.

Since then, if the revolutions of the disc were uniform, that is, if the motion of the carriage were uniform during any exceedingly small time, the motion of the wheel F would vary as the force of *traction*, and that evidently, if the force of traction were constant, the motion of the wheel F would vary directly as the motion of the carriage during the same time, it follows (by a well-known principle of variation), that if both the force of traction and the motion of the carriage were variable, the motion of the wheel F would vary as their product; and this being true of every exceedingly small period of the motion, it follows that the whole motion of the wheel F during any finite time, however long, is proportional to the sum of the products obtained by multiplying each elementary space described by the carriage, by the particular force of traction under which that elementary space is described, or, in other words, that the whole space moved over by the circumference of the wheel F is directly proportional to the whole *work*, or dynamical effect expended in moving the carriage, however varied the traction or the velocity may have been. It was to an application to the steam indicator of that admirable and fruitful principle of M. Poncelet, which combines the motions of the wheel F and the disc B D, and which, in fact, performs the complex operation known in analysis as integration—integrating the traction, considered as a function of the space—that the attention of the Committee was specially directed by the Association, and that their labours have particularly been devoted. The indicator which they have now the honour to present to the Association has nothing in common with the instrument which has just been described, except the *principle* of M. Poncelet and the *springs* of M. Morin; these have been constructed according to the formulæ given by that gentleman in his work already quoted (Appareil Dynamometrique, &c.), and have been found admirably adapted to their use. The original design or project of the machine was given by Professor Moseley, and he being the only member of the Committee resident in London, the execution of it was placed under his direction.

PROFESSOR MOSELEY'S INDICATOR.

The accompanying engraving (Plate VI.) represents the indicator constructed by the Committee. C and D are cylinders, each four inches in length, communicating by the steam-pipes A and B with the top and bottom of the cylinder of the engine to which the indicator is applied, and well clothed with felt to prevent radiation. In these cylinders work two solid pistons, each four square inches in area, fixed upon the extremities of the same piston-rod E F, which piston-rod (when the steam passages A and B are open and the indicator is in action) sustains in the direction of its length a pressure equal to the difference between the pressures upon the two pistons fixed upon its extremities, or (since these sustain the same pressure with equal portions of the opposite sides of the piston of the engine) equal to the *effective* pressure of the steam on four square inches of the piston of the engine. This pressure upon the piston-rod is made to bear, by means of a shoulder Z, upon the steel spring S T, which spring is connected by means of links at its extremities with a second similar and equal spring Q R, supported at its centre upon a solid projection P, from the cast-iron frame of the instrument. The pressure of the piston-rod upon the lower spring borne at the extremities of the upper spring, whose centre is fixed, is thus made to separate the two springs from one another, and the separation produced is, by a well-known law of deflection, directly proportional to the pressure sustained, so long as the deflections are small. The limits within which this law of deflection obtains, are greatly extended by the peculiar form given to these springs, first suggested (it is believed) by M. Morin. One surface of each spring is plane, and the opposite surface of that well-known parabolic form by which an equal *strength* is given to every portion of the length of the spring. The spring being thus tapered from its centre to its extremities without impairing its strength, its deflection is distributed more uniformly throughout its length*, and being thus made less (for a given separation of the springs) at every point, the elastic limits are nowhere so soon passed.

By this connexion of the piston-rod with the springs, its position is made to vary directly as the effective pressure upon its extremities, or as the effective pressure upon four square inches of the piston of the engine, so that every additional pound in that pressure will cause the piston-rod to alter its position by the same additional distance in the direction of its length.

The pulley or wheel I K (which, from the peculiar functions assigned to it in this machine, we propose to call the *integrating* wheel,) turns upon the piston-rod as its axis, and traverses with it at the same time in the direction of its length, being prevented from moving on it in that direction by means of two shoulders fixed by adjustment screws.

The arms of this wheel are pierced by apertures, through which pass three rods united at their extremities (as shown in the figure), so as to form the rigid frame G H, which frame turns also upon the piston-rod as its axis, but does not traverse with it in the direction of its length; so that the wheel I K is made by its motion with the piston-rod to traverse the rods of the frame longitudinally, whilst it is made to sweep the frame round with it by any motion of rotation which may at the same time be communicated to it about its axis. It receives such a motion of rotation from the cone K L, which is so placed that its side may be accurately parallel to the piston-rod, and which is kept continually pressed against the wheel at K by means of a spiral spring inclosed in a tube at M, and acting continually against the extremity of the spindle on which the cone turns.

A system of bevel wheels U, Y, X, communicates to this spindle, and with it to the cone, the rotation of the pulley N, which pulley is driven by a cord carrying a weight at one extremity, and passing by the other extremity (over directing pulleys) to the piston of the engine, or to some point which moves *precisely as the piston of the engine does, but through a less space.* The circumference of the pulley N being thus made to move precisely as the piston of the engine, the angle described by the cone, during any exceedingly small period of time, is made to be exactly proportional to the space described during that time by the piston of the engine. Now let it be observed, that the circumference of the integrating wheel I K partaking of the motion of that portion of the surface of the cone with which it is at any instant in contact, the number of revolutions, or rather parts of a revolution, which it is made to describe during any exceedingly small period of time, beginning from that instant, is dependent upon two causes; first, upon the angle which the cone describes about its axis during that small period of time, and secondly, upon the distance of its point of contact K with the cone from the apex of the cone at that time. Moreover, that if either of these two elements of variation remained always the same, then the number of revolutions, or parts of a revolution, made by the wheel, would vary directly as the other, whence it follows, by a well-known principle of variation, that when (as in the present case) both these elements vary, it varies as their product; or that the number of revolutions, or parts of a revolution, made by the integrating wheel during any exceedingly small period of time, varies directly as the product of two factors, of which one is the angle described during that time by the cone, and the other the distance of the point of contact K of the cone and wheel from the apex of the cone.

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* An absolute *uniformity* of *deflection* throughout the length of the spring is not obtained by the construction of M. Morin, but only a uniformity of *strength*; the two objects are not compatible. It would, perhaps, be more expedient for the use here given to the springs, that, by a different but equally simple law of the variation of their thickness, they should be made to bend uniformly throughout.

Now the former of these factors has been shown to vary directly as the space described during that small period of time by the piston of the engine, and the latter to vary directly as the effective pressure which the steam is then exerting upon the piston of the engine*.

Thus, then, it appears that the number of revolutions, or parts of a revolution, made during any exceedingly small period of time by the integrating wheel, varies as the product of the space described by the piston of the engine during that time, by the effective pressure of the steam upon it during that time, that is, it varies as the *work* or *dynamical effect* of the steam upon the piston during that time. And this being true in respect to every small period of the time during which the stroke of the engine is in progress, is true of the whole stroke; whence it follows, that the number of revolutions, and parts of a revolution, made by the integrating wheel during the stroke is proportional to the whole work, or dynamical effect of the steam upon the piston during the stroke.

The integrating wheel carries round with it the frame G H, on the hollow axis of which frame is fixed a pinion running into a wheel, whose axis turns upon bearings fixed to the frame of the instrument, and the number of whose teeth is to that of the teeth in the pinion as ten to one. This wheel carries also a pinion running into a second wheel, their numbers of teeth being in the same proportion, and so through a train of five wheels and pinions. The circumference of each of the four last wheels is divided into ten equal parts and numbered, and the circumference of the first into 100. The number of revolutions of the integrating wheel is thus registered to five places of integers, and to one place of decimals.

Now this number of revolutions has been shown to be proportional, in respect to each stroke, to the work done by the steam upon the piston during that stroke; if therefore the action of the indicator continued the same during successive strokes, or if the direction of the pressure of the steam upon the piston, and that of the motion of the piston, were not reversed at every stroke, then would the number registered during any number of strokes of the engine be directly proportional to the work done by the steam upon its piston whilst that number was registered. At the return-stroke of the piston of the engine, the pulley N, however, revolves backwards, and supposing it to carry with it the spindle of the cone, the cone also revolves backwards, so that if the integrating wheel remain in contact with the cone at any other point than its apex, it too will be made to revolve backwards, and the number registered in the preceding stroke will thus be *diminished* by the number of revolutions made by the integrating wheel during this stroke: but let it be observed, that before the motion of the piston of the engine is reversed, the direction of the pressure of the steam upon it, and therefore the direction of the pressure upon the piston-rod of the indicator, is reversed, by which altered direction of the pressure, as well as by the elasticity of the springs, the integrating wheel is made to ascend to the apex of the cone, and to remain there during the return-stroke, so that no number whatever is registered during that stroke.

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* The position of the integrating wheel upon the piston-rod is so adjusted, that before the steam is admitted the integrating wheel may be brought by the elasticity of the springs exactly to the apex of the cone. In order to prevent it from being stopped by the apex of the cone, if accidentally it should be made to pass it, a solid piece projects from the frame of the instrument, having its surfaces adjusted so as to receive the edge of the wheel when it is forced beyond the apex of the cone, and to serve as a stop to the motion of the cone in the direction of its spindle when the resistance of the wheel is thus removed from it.

Thus, then, the remaining number registered during any time by the instrument when applied to the double acting engine, is proportional to the work done upon the piston by the steam at the alternate strokes during that time. The mathematical formula by which the work is determined from this number, and allowance made for the friction of the indicator, is given in a subsequent part of this Report.

In order effectually to guard against any error which might accidentally result from the reversed motion of the piston, a contrivance has been introduced in the combination of wheels Y, X, U, by which the revolution of the cone may be arrested whilst that reversed motion takes place. To adapt the instrument to register (if required) the work done at *every* stroke of the piston, a four-way cock has been constructed, which may be made, by the action of the engine, to control the direction of the steam passages of the indicator, in such a way that the upper cylinder C shall always communicate with that portion of the cylinder of the engine which is filled with steam, whilst the lower cylinder D is made always to communicate with the vacuum. When the indicator is thus used, the cone is made, by a simple adjustment of the mechanical combination U X Y, to revolve constantly *forwards*, whilst the motion of the piston of the engine, and therefore of the pulley N, *alternates*. It remains now only to speak of the application of the indicator to the single acting engine, or Cornish engine.

The registration during the down or in-doors stroke of that engine is already explained. During the first portion of the *up* or out-of-doors stroke the equilibrium valve is opened, and the pressure upon both the pistons of the indicator thus becoming the same, the integrating wheel is brought by the elasticity of the springs to its initial position at the apex of the cone, and thus, although the cone turns backwards, the wheel remains at rest and nothing is registered. When the equilibrium valve closes, the pressure of the steam in the upper portion of the cylinder of the engine, and therefore in the upper cylinder C of the indicator, preponderates; the integrating wheel descends from the apex of the cone and the register revolves backwards, deducting from, or diminishing, the number before registered by precisely the number of units of work which is done by the steam (jammed back into the upper portion of the cylinder) *against* the returning piston. Now this is precisely the deduction which the theory of the steam-engine shows ought in this case to be made, and the registration of each double stroke of the single acting or Cornish engine is, by this backward movement of the integrating wheel, *perfected*. Let it be here observed, that the indicator in the *down*-stroke performs the definite integration of a *logarithmic function*, viz. that which represents the pressure of the steam as a function of space, described by the piston during the expansion of the steam, that it then calculates the numerical amount of the integral it has thus completed, and registers that amount;

that it performs a similar operation in the up-stroke, and deducts the corresponding amount as a correction from the first.

The above must be received as an attempt to place the theory of the instrument under a general and popular form. A mathematical discussion of it accompanies this Report, in which the corrections due to friction and other causes are fully considered.

The instrument will be observed to differ from that invented by M. Morin for applying the same principle of M. Poncelet to estimate the traction of carriages, as well in those contrivances which are specially required by its application to the steam-engine, as in the following important particulars, which are wholly independent of that particular application.

First, the surface of a cone is here substituted for the plane surface of a circular disc, an arrangement by which the rapidity of the changes of velocity due to corresponding changes in the position of the integrating wheel is diminished in the same proportion in which the sine of one half the angle of the cone is less than unity; and the force necessary to drive the integrating wheel is diminished in the same proportion, and therefore the chance of an error arising from the slipping of the edge of the integrating wheel on the surface, which gives it motion in the like proportion.

Secondly, it differs from the Compteur of M. Morin in the separation of the registering apparatus from the integrating wheel, by the contrivance of the frame and guides, by which separation, whilst the springs are relieved from the effect of the *momentum* and the friction due to the *weight* of the registering apparatus, this last being brought to a state of quiescence, the registration is made legible whilst the indicator is in action.

THEORY OF THE INDICATOR.

Let N represent the number of revolutions, and parts of a revolution, made by the integrating wheel and registered by the indicator, whilst L feet are described by the piston of the engine.

Also let $\frac{L}{m}$ represent the space described in the same time by the cord which passes over the pulley N, this cord being supposed to move precisely as the piston of the engine does, but through one mth of the space.

Let R represent the radius of the pulley N in inches.

Let r represent the radius of the piston of the indicator in inches.

Let ρ represent the radius of the integrating wheel I K in inches.

Let ι represent half the angle at the apex of the cone.

Δ N the number registered by the indicator, whilst the exceedingly small space Δ L is described by the piston of the engine.

λ the additional separation of the springs in inches due to each additional pound of strain upon the springs, or to each additional pound of effective pressure on the piston-rod of the indicator. P the effective pressure of the steam on the piston of the engine, and therefore on that of the indicator, in pounds per square inch, at that period of the stroke when the space Δ L begins to be described and the number Δ N to be registered. F the whole friction opposed to the motion of the piston-rod in the direction of its length. The effective pressure upon the piston-rod of the indicator at that time in pounds is represented, therefore, by $\pi r^2 P \mp F$, the sign $\mp$ being taken according as the steam pressure is in the act of increasing or diminishing, or the piston of the indicator moving in the direction of the pressure of the steam upon it, or in the opposite direction; and since each pound of this pressure produces a separation of λ inches in the springs, therefore the whole separation of the springs, or the whole distance of the point of contact of the integrating wheel with the surface of the cone, from the apex of the cone, measured along its side, is represented by $(\pi r^2 P \mp F)\lambda$. Whence it follows that the radius of the circle, which this point is in the act of describing by reason of the revolution of the cone, is represented in inches by $(\pi r^2 P \mp F)\lambda \sin \iota$. Also the space described by the cord, which passes round the pulley N, and therefore by the circumference of that pulley, whilst the number ΔN is registered, is represented in inches by $\frac{12}{m}\Delta L$; and this pulley carries round with it the cone, so that the space in inches described by a point in the cone at distance *unity* from its axis, whilst the number ΔN is registered, is represented by $\frac{12}{m R}\Delta L$. Now let the pressure P upon the piston of the engine be conceived to remain unchanged, whilst the exceedingly small space ΔL is in the act of being described by it, the piston-rod of the indicator will then remain at rest during that time; and the point of contact of the integrating wheel with the surface of the cone will, during that time, describe the arc of a circle whose radius is represented by $(\pi r^2 P \mp F)\lambda \sin \iota$, and which subtends at its centre an angle measured (at distance unity) by $\frac{12}{m R}\Delta L$. The length of this arc described by the point of contact of the cone with the integrating wheel, and therefore by the circumference of the latter, whilst ΔN is registered, is represented therefore, on the above supposition, by

$$\frac{12}{m R}\cdot \Delta L \cdot (\pi r^2 P \mp F)\lambda \sin \iota.$$

But since the circumference of the integrating wheel is represented by $2\pi\rho$, its circumference describes a space represented by $2\pi\rho\,\Delta N$, whilst ΔN revolutions, or parts of a revolution, are made by it:

$$\therefore \frac{12}{m R}\cdot \Delta L \cdot (\pi r^2 P \mp F)\lambda \sin \iota = 2\pi\rho \cdot \Delta N$$

$$\therefore P \cdot \Delta L = \frac{R m \rho}{6 r^2 \lambda \sin \iota}\cdot \Delta N \pm \frac{F}{\pi r^2}\cdot \Delta L$$

$$\therefore \Sigma P \cdot \Delta L = \frac{R m \rho}{6 r^2 \lambda \sin \iota}\cdot N \pm \frac{F}{\pi r^2}\cdot L,$$

where $\Sigma P \cdot \Delta L$ represents the sum of all the different pressures P upon a square inch of the piston, when situated at as many different points of the length L of its stroke, each such pressure in pounds being first multiplied by a space ΔL in feet, which the piston is supposed to describe under that pressure remaining constant. Now this equation obtains, however small the spaces may be taken which are represented by ΔL, through each of which spaces the pressure upon the piston is supposed to remain constant; it obtains therefore if the spaces be taken *infinitely* small, or if each pressure be supposed to remain constant only through an infinitely small space, or, which is the same thing, if the pressure *constantly vary*, which is the *actual* case; and in this case the sum of all such products of the pounds in the pressure upon a square inch of the piston by the feet in the space described under that pressure, is evidently the effective *work* done by the steam upon a square inch of the piston through the space L, estimated in pounds one foot high. Let this number of units of work be represented by U,

$$\therefore U = \frac{R m \rho}{6 r^2 \lambda \sin \iota} N \pm \frac{F}{\pi r^2}\cdot L, \ldots\ldots\ldots\ldots\ldots \quad (1.)$$

which formula determines (in pounds one foot high) the work U done by the steam upon each square inch of the piston of the engine whilst the space L (in feet) is described by it, and the number N registered by it. Whilst the number N is registered by the indicator, L is shown by the ordinary counter, and the number U thus determined being multiplied by the number of square inches in the piston of the engine, will give the whole work yielded by the steam.

The sign ± is to be taken according as the steam pressure P is in the act of increasing or diminishing, or as the piston of the indicator is in the act of yielding to the pressure of the *steam* upon it, or to the pressure of the *springs*; or according as the friction F, which is always opposed to the direction in which it is moving, is acting in a direction *opposite* to the pressure of the steam upon it or in the *same* direction. An ambiguity results, therefore, from the introduction of this sign, which is got rid of in the case of ordinary or double acting engines, by the consideration that in such engines the steam pressure *increases* only during an exceedingly small period of time, whilst the steam-valve is in the act of opening, during which small period of time the piston of the engine remains at rest; at the expiration of this time the distance of the wheel from the apex of the cone is less, by reason of the friction; the positive sign is therefore to be taken whilst it remains at this distance, that is, until the expansion begins. Throughout the rest of the stroke the steam pressure diminishes, and the negative sign is to be taken. Thus, if the steam be expanded p times, the correction for friction becomes

$$+\frac{F}{\pi r^2}\cdot\frac{L}{p}-\frac{F}{\pi r^2}\left(1-\frac{1}{p}\right)L, \text{ or } -\frac{FL}{\pi r^2}\left(1-\frac{2}{p}\right)$$

In respect to double acting engines, therefore, and generally of all engines except the Cornish engines, we have

$$U=\frac{Rm\rho}{6r^2\lambda\sin\iota}N-\frac{FL}{\pi r^2}\left(1-\frac{2}{p}\right)\ldots\ldots\ldots\ldots\ldots(2.)$$

In the Cornish engines, when the down-stroke has been completed and the equilibrium valve opened, the piston of the indicator is relieved of all pressure, and the integrating wheel ascends to the apex of the cone, and remains there as long as the valve remains open; it ceases therefore to partake in the revolution of the cone during that time, and no number is registered. The closing of the equilibrium valve produces again an excess of pressure on the superior surface of the piston of the engine and of the indicator, and the integrating wheel begins to descend from the apex of the cone, and to be carried round by it in the opposite direction to its former revolution, this pressure continually increasing until the stroke is completed; the formula must be taken, in respect to this period of the action of the indicator, with the positive instead of the negative sign; so that if N_2 represent the number registered in a *reverse* order by the indicator when applied to a Cornish engine, or the number which the indicator subtracts in the up-strokes from the number N_1 registered by it in the down-strokes, and if the equilibrium valve be supposed to be closed when $\frac{1}{n}$th of the stroke remains to be completed; so that if L represent the space described in the down-strokes of the engine whilst N_1 is registered, $\frac{1}{n}$ L will represent the space described in the up-strokes of the piston whilst the number N_2 is in the act of being registered; then representing the units of work done upon a square inch of the piston during the down-strokes by U_1, and during the up-strokes (*against the load*) by U_2, we have

$$U_1=\frac{Rm\rho}{\sigma r^2\lambda\sin\iota}N_1-\frac{FL}{\pi r^2}\left(1-\frac{2}{p}\right)$$

$$U_2 = \frac{R m \rho}{\sigma r^2 \lambda \sin \iota} N_2 + \frac{F}{\pi r^2} \frac{1}{n} L$$

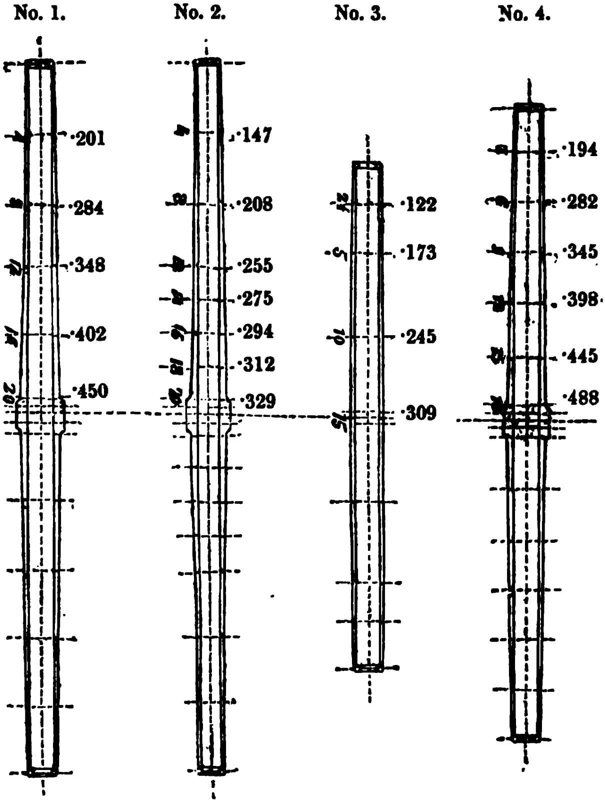
$$\therefore U_1 - U_2 = \frac{R m \rho}{\sigma r^2 \lambda \sin \iota} (N_1 - N_2) - \frac{F}{\pi r^2} \left(1 - \frac{2}{p} + \frac{1}{n}\right) L.$$

Now $N_1 - N_2$ represents the *residual* number N actually registered by the indicator, and $U_1 - U_2$ represents the whole work U done by the engine upon each square inch of the piston in favour of the load:

$$\therefore U = \frac{R m \rho}{\sigma r^2 \lambda \sin \iota} N - \frac{(n+1) F}{n \pi r^2} L. \ldots\ldots\ldots\ldots\ldots (3.)$$

THE SPRINGS.

Four sets of springs were constructed of the forms and dimensions represented in the accompanying figures. The thickness of each spring, in decimal parts of an inch, at different distances from its extremities, is shown by the numbers upon the corresponding figure.



The following tables contain the results of experiments made, with great care, by Mr. Timme to determine the law of deflection in the springs constructed for the Committee, and the particular value of the constant λ in respect to each.

Spring No. 1, (shear steel, length 30 inches) mean value of λ = ·028.

Load in lbs.	Separation in inches by experiment.		Separation in inches by calculation, the additional deflection λ due to each lb. being assumed = ·028.	
	First Experiment, July 21.	Second Experiment, October 14.	First Experiment.	Second Experiment.
lbs.	in.	in.	in.	in.
0	1·5	1·52	1·5	1·52
10	1·8	1·81	1·78	1·80
20	2·09	2·11	2·06	2·08
30	2·37	2·4	2·34	2·36
40	2·64	2·68	2·62	2·64
50	2·93	2·97	2·90	2·92
60	3·22	3·25	3·18	2·20
70	3·48	3·53	3·46	3·48
80	3·76	3·82	3·74	3·76
90	4·02	4·1	4·02	4·04
100	4·31	4·37	4·30	4·32
110	4·60	4·65	4·58	4·60
120	4·86	4·92	4·86	4·88
130	....	5·19	....	5·17

This spring, when the same weights were taken off in succession, showed identically the same deflections as when they were added.

Spring No. 2, (cast steel, length 30 inches) mean value of λ = ·068.

Load in lbs.	Separation in inches by experiment.		Separation in inches by calculation, the additional deflection due to each lb. being assumed = ·068.	
	First Experiment, the weights added.	Second Experiment, the weights taken off.	First Experiment.	Second Experiment.
lbs.	in.	in.	in.	in.
0	1·48	1·49	1·48	1·49
5	1·84	1·84	1·82	1·82
10	2·17	2·21	2·16	2·17
15	2·53	2·56	2·50	2·51
20	2·88	2·91	2·84	2·85
25	3·22	3·25	3·18	3·19
30	3·57	3·6	3·52	3·53
35	3·91	3·94	3·86	3·87
40	4·25	4·27	4·20	4·21
45	4·56	4·6	4·54	4·55
50	4·88	4·92	4·88	4·89

Spring No. 3, (cast steel, length 40 inches) mean value of $\lambda = \cdot1115$.

Load in lbs.	Separation in inches by experiment.		Separation in inches by calculation, the additional deflection λ due to each lb. being assumed $= \cdot1115$.	
	First Experiment, the weights added.	Second Experiment, the weights taken off.	First Experiment.	Second Experiment.
lbs.	in.	in.	in.	in.
0	1·83	1·82	1·83	1·82
5	2·38	2·39	2·38	2·37
10	2·95	2·96	2·93	2·92
15	3·51	3·52	3·48	3·47
20	4·07	4·08	4·03	4·02
25	4·63	4·63	4·58	4·57
30	5·17	5·17	5·13	5·12
35	5·71	5·73	5·68	5·67
40	6·24	6·24	6·23	6·22

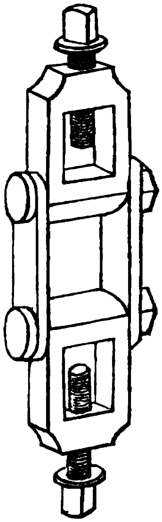
Spring No. 4, (cast steel, length 40 inches) mean value of $\lambda = \cdot0489$.

Load in lbs.	Separation in inches by experiment.		Separation in inches, the additional deflection λ due to each lb. being assumed $= \cdot0489$.	
	First Experiment, the weights added.	Second Experiment, the weights taken off.	First Experiment.	Second Experiment.
lbs.	in.	in.	in.	in.
0	1·72	1·72	1·72	1·72
10	2·21	2·23	2·209	2·209
20	2·72	2·73	2·698	2·698
30	3·21	3·22	3·187	3·187
40	3·69	3·7	3·676	3·676
50	4·18	4·19	4·165	4·165
60	4·66	4·67	4·654	4·654
70	5·14	5·15	5·143	5·143

In the interval of two months between the two sets of experiments, of which the results are given in the first of the above tables, the springs had been for some days worked in the indicator upon Mr. Fairbairn's engine at Mill-wall. At the time of the first series they were fresh from the hands of the workmen. It will be observed, that whilst no change whatever has taken place in the elasticity or the law of the deflection (the mean value of λ remaining the same), a change, or *set* of ·004 inch, has been produced in the *initial*, or permanent separation of the springs. This set was to be expected. The error which might result from it is perfectly corrected (the mean value of λ remaining the same) by an equivalent alteration of the position of the integrating wheel upon the rod, for which alteration an adjusting screw is provided.

The deflection of the spring No. 2 is greater than that theoretically due to the dimensions assigned to it; this error has resulted from a fault in the construction, the piece which forms the centre of the spring, and is pierced by the apertures through which the piston-rod passes, which piece is intended to be rigid, and to serve merely as an attachment to the elastic arms of the spring, having been constructed (by a mistake of the workman) greatly too thin, and the apertures in it of too large a diameter. These causes seem not only to have affected the limits of the deflection of the spring, but (in some degree) its elasticity.

Springs of different degrees of elasticity are required, that the same, or nearly the same, deflection and play of the pistons of the indicator may be obtained when it is applied to engines working at different steam pressures. A moveable link, represented in the accompanying figure, has, however, been applied to obtain the same deflection from the *same* pair of springs under a comparatively small variation in the pressure to which they are subjected. The two permanent links which unite the two springs of any system are removed and replaced by two such moveable links, which are clamped upon the springs by means of the screws shown in the figure, at such distances from their extremities, as may, by shortening the *arms* of the spring, reduce the deflection due to a given strain to the required limit. If this removal of the link from the extremity of the spring be, however, carried beyond two, or at the utmost three inches, the increased rigidity of the shortened arm and other causes, will begin to affect the elastic properties of the springs towards the limits of their deflection.

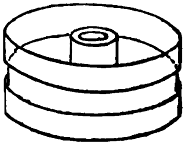


FRICTION OF THE PISTONS, INTEGRATING WHEEL, &c.

It will be observed that the entire amount of that friction F which affects the registration of the instrument is due to two causes, of which the first is that constant friction of the pistons which results from the precautions necessary to prevent the escape of the steam, and the second that which is due to the pressure of the cone, which is of brass, upon the integrating wheel acting in the direction of the axis of the cone, and produced by the pressure of the spring upon the extremity of its spindle.

By this last pressure friction is produced,—1st, at the point of contact of the integrating wheel with the cone, and 2ndly, at the point of contact of the integrating wheel with the piston-rod upon which it turns, and which serves it as an axis.

Every precaution has been taken to diminish the friction which results from these several causes. The pistons have been made hollow, as shown in the accompanying figure. Each may be conceived to be formed of a thin brass cylinder or tube, accurately fitting to the cylinder of the indicator, when heated to the temperature of the steam, and crossed in its centre by a rigid diaphragm or plate, about one-fourth of an inch thick, in which the piston-rod is fixed. That part of the surface of the piston which immediately surrounds this solid plate is hollowed into a groove, so that no rigid portion of the mass of the piston is brought in contact with the interior of the cylinder of the indicator, and thus the possibility of the surfaces binding upon one another by the expansion of one of them is avoided, and any uncertain influence on the results from this cause guarded against. To draw off the water of condensation the diaphragm of



this piston is pierced by a tube, which passes through the bottom of the cylinder, and is closed by a cock placed in such a position that it may be opened and the water drawn off without stopping the indicator. To ensure a uniform lubrication, a grease-cock is inserted in the top of the cylinder. To reduce to the utmost the friction which results from the pressure of the spring on the spindle of the cone, the sensibility of the cone to the action of the spring is rendered as great as possible by diminishing the bearing surface of the spindle, and causing the spring (which is a spiral spring inclosed in a tube) to press accurately on the centre of the extremity of the spindle. These precautions being taken, an exceedingly slight pressure of the spring is found to be sufficient to produce that friction between the integrating wheel and the cone which is required to drive the registering apparatus. It was in the correct transmission of the motion of the cone to the integrating wheel that the greatest difficulties were predicted, and that the least have been found.

The following expedient was applied to determine the whole amount of the prejudicial friction.

The instrument being put into the same condition in every respect in which it would be applied to the engine, was fixed firmly in an upright position, and the bottom of the lower cylinder being taken off, a hook was attached to the centre of the piston working in that cylinder. To this hook weights were attached, increasing in the same order in which they were increased for the *separate* trial of the same system of springs as was now placed in the instrument. When each weight had thus been added, and the pistons brought to their corresponding positions in the cylinders and the integrating wheel to its corresponding place upon the cone, the piston-rod, carrying with it the pistons and integrating wheel, was gently depressed by the hand until the lowest position was found at which it would rest, and in this position the separation of the springs was accurately measured. The difference between this separation and that produced by loading with the same weight the same springs before they were placed in the instrument, was seen to be due to two causes, first, to the weight of the connected system of the pistons, piston-rod, and integrating wheel, all of which weight (in this state of the equilibrium of the system bordering upon motion *upwards*) was borne by the springs; and secondly, it was due to the friction, which in that particular position of the system was opposed to its motion upwards. Now the moveable system of the pistons, piston-rod, and integrating wheel being accurately weighed, and the deflection of the springs due to each pound having been before accurately determined, the deflection due to the former cause was accurately known, and therefore that due to the latter, *i.e.* to the friction. The deflection of the springs due to the friction of the instrument in every position of the pistons being thus found, the mean deflection due to this cause was known, and therefore the mean amount of this friction. A series of experiments was thus made, with great care and accuracy, by Mr. Timme, three of the springs being successively placed in the instruments, and the weights gradually added and gradually taken off. A slight variation was found in the friction in different positions of the piston, its greatest amount being uniformly found in the lowest position. This difference may in some degree be due to a slight inaccuracy of workmanship; it is, however, no doubt, principally to be attributed to the fact, that a larger portion of the circumference of the integrating wheel is brought in contact with the surface of the cone in the lower than in the higher positions of the former, and that by reason of the milled edge of the wheel ploughing slight furrows* on the brass surface of the cone; the friction of these two surfaces is made to deviate from the ordinary laws of friction, and to be proportional partly to the pressure and partly to the extent of the surface of contact. The following are the tabular results of experiments made by Mr. Timme with springs No. 1, No. 3, and No. 4.

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* These furrows have been rendered so slight as to produce no sensible injury to the surface of the cone, by increasing the sensibility of the spindle to the action of the spiral spring on its extremity.

Similar experiments will be repeated when the indicator shall have been for some time in operation, and when the cylinders are at the temperature of the steam. From the peculiar construction of the pistons, it is not, however, anticipated that there will be much difference in the results of these experiments.

Spring No. 1, λ = ·028.

Weight suspended in lbs.	Deflection when the piston-rod was brought to the lowest point at which it would remain.	Deflection when the springs were loaded with the same weights before they were placed in the instrument.	Difference of the deflections in the two preceding columns, being that due to the weight of the pistons, wheel, and rod, and to the friction.	Deflection due to the friction found by subtracting the deflection due to the weight, 3 lb. 0¼ oz., of the piston, &c., from the preceding column.
lbs.	in.	in.	in.	in.
0	1·65	1·52	·13	·045125
10	1·93	1·81	·12	·035125
20	2·22	2·11	·11	·025125
30	2·49	2·4	·09	·005125
40	2·79	2·68	·11	·025125
50	3·07	2·97	·10	·015125
60	3·36	3·25	·11	·025125
70	3·66	3·53	·13	·045125
80	3·95	3·82	·13	·045125
90	4·24	4·1	·14	·055125
100	4·52	4·37	·15	·065125

Mean deflection due to friction = ·035125 in.
Mean friction = 1·2545 lb.

Spring No. 3, λ = ·11.

Weight suspended in lbs.	Deflection when the piston-rod was brought to the lowest point at which it would remain.	Deflection when the springs were loaded with the same weights before they were placed in the instrument.	Difference of the deflections in the two preceding columns, being that due to the weight of the pistons, wheel, and rod, and to the friction.	Deflection due to the friction found by subtracting the deflection due to the weight, 3 lb. 0¼ oz., of the pistons, &c., from the preceding column.
lbs.	in.	in.	in.	in.
0	2·27	1·83	·44	·10656
5	2·82	2·38	·44	·10656
10	3·39	2·95	·44	·10656
15	3·99	3·51	·48	·14656
20	4·55	4·07	·48	·14656
25	5·15	4·63	·52	·18656
30	5·66	5·17	·49	·15656

Mean deflection due to friction = ·13656 in.
Mean friction = 1·2414 lb.

Spring No. 4, $\lambda = \cdot 049$.

Weight suspended in lbs.	Deflection when the piston-rod was brought to the lowest point at which it would remain.	Deflection when the springs were loaded with the same weights before they were placed in the instrument.	Difference of the deflections in the two preceding columns, being that due to the weight of the pistons, wheel, and rod, and to the friction.	Deflection due to the friction found by subtracting the deflection due to the weight, 3 lb. 0¼ oz., of the pistons, &c., from the preceding column.
lbs.	in.	in.	in.	in.
0	1·92	1·72	·20	·05147
10	2·41	2·21	·20	·05147
20	2·90	2·72	·18	·03147
30	3·39	3·21	·18	·03147
40	3·88	3·69	·19	·04147
50	4·4	4·18	·22	·07147
60	4·89	4·66	·23	·08147
70	5·37	5·14	·23	·08147

Mean deflection due to friction = ·0552 in.
Mean friction = 1·1264 lb.

FORMULÆ FOR DETERMINING THE WORK OF AN ENGINE BY MEANS OF THE INDICATOR.

The following are the values of the constants which enter into the general equation in its application to the indicator constructed by the Committee.

Radius of the integrating wheel . . . = ρ = 2·99 in.
Radius of the piston of the indicator = r* = 1·125 in.
Radius of the pulley measuring to the centre of the cord = R = 3 in.
Angle at apex of cone . . . . = $2\iota = 90^\circ$.
Friction of piston, of integrating wheel on cone, &c. &c., mean value = F = 1·2074 lb.

$$\text{Additional deflection of springs due to each additional pound of pressure on piston of indicator.} \left\{ = \lambda \begin{array}{l} \text{Spring No. 1.} = \cdot 028 \\ \text{Spring No. 2.} = \cdot 068 \\ \text{Spring No. 3.} = \cdot 1115 \\ \text{Spring No. 4.} = \cdot 0489. \end{array} \right.$$

Substituting the above values of ρ, r, R, ι in equations (2.) and (3.), we obtain for double acting engines,

$$U = 1\cdot 67052 \left(\frac{m}{\lambda}\right) N - \tfrac{1}{4} F . L \ldots\ldots\ldots\ldots\ldots \quad (4.)$$

for single acting Cornish engines,

$$U = 1\cdot 67052 \left(\frac{m}{\lambda}\right) N - \tfrac{1}{4}\left(1 + \frac{1}{n}\right) F . L \ldots\ldots \quad (5.)$$

If in these equations we substitute the values of λ for the different systems of springs, and also the *mean value* of F, which is 1·25 lb., we shall obtain for *spring No.* 1, $\lambda = \cdot 028$ in.

$$U = 59\cdot 6614\, m N - \cdot 3018 \text{ L} \quad \text{(common engine).}$$

$$U = 59\cdot 6614\, m N - \cdot 3018 \left(1 + \frac{1}{n}\right) \text{L} \quad \text{(Cornish engine).}$$

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* The radius of the piston is so taken that its area may equal exactly four square inches.

Spring No. 2, $\lambda = 0{\cdot}68$.

$$U = 24{\cdot}566\, m\, N - {\cdot}3018\, L \quad \text{(common engine).}$$

$$U = 24{\cdot}566\, m\, N - {\cdot}3018 \left(1 + \frac{1}{n}\right) L \quad \text{(Cornish engine).}$$

Spring No. 3, $\lambda = {\cdot}1115$.

$$U = 14{\cdot}982\, m\, N - {\cdot}3018\, L \quad \text{(common engine).}$$

$$U = 14{\cdot}982\, m\, N - {\cdot}3018 \left(1 + \frac{1}{n}\right) L \quad \text{(Cornish engine).}$$

Spring No. 4, $\lambda = {\cdot}0489$.

$$U = 34{\cdot}162\, m\, N - {\cdot}3018\, L \quad \text{(common engine).}$$

$$U = 34{\cdot}162\, m\, N - {\cdot}3018 \left(1 + \frac{1}{n}\right) L \quad \text{(Cornish engine).}$$

The values of U, obtained from the above formulæ, being multiplied by the number of square inches in the surface of the piston of the engine, will give the whole number of units of work yielded by it during the time of the experiment.

It will be observed, that no account is taken in these formulæ of the weight (3 lbs. 0½ oz.) of the pistons, the integrating wheel, and the rod to which these are attached. The influence of this weight is, in fact, allowed for when, the springs being placed in the indicator, and therefore loaded with it, and sustaining no other pressure, the integrating wheel is moved to such a position upon the rod as that its circumference may coincide with the apex of the cone. The springs are then just so much deflected as by their elasticity to sustain this weight, and that initial deflection remaining superadded to any additional deflection to which they may be subjected by the additional strain thrown upon them, the weight of the pistons, &c. will in every position be accurately balanced by it, and the additional strain thrown upon the springs will produce precisely the same deflections as though no such weight existed.

In conclusion, the Committee are desirous to express their obligations to Mr. Dutton, foreman to Mr. Fairbairn at Manchester, for a valuable suggestion made by him, and adopted by them*; to Mr. Holtzappfel for the excellent workmanship of the machine; and to include in this acknowledgement their sense of the valuable services of his draughtsman, Mr. Timme, whose name is several times mentioned in this Report, and whose intelligent and persevering attention have greatly facilitated its construction.

They regret that the construction of the instrument has been attended by numerous delays, and that it has not been so far completed as to admit of being applied to an engine for a trial until within one week of the date of this Report. By the kindness of Messrs. Fairbairn and Murray they were then allowed to place it on their engine at Mill-wall. The object of that trial was simply to determine whether the *mechanical* difficulties opposed to its construction, on which much stress had been laid, and in respect to which a failure had been predicted, had in reality been overcome; on this point the trial supplied a decisive answer. Every part of the instrument performed the mechanical functions assigned to it with entire precision and accuracy, except the pistons, which have been replaced by others more accurately fitted to the cylinders.

* It was at the suggestion of Mr. Dutton that a single cylinder was replaced by two cylinders; the instrument was thus made to assume a more compact and convenient form, and much was gained, practically, in that correctness and facility of workmanship which results from making the cylinders themselves the guides of the piston-rod, and dispensing with the stuffing-boxes.

It remains now to the Committee to apply the indicator to some of the engines whose work is registered by other means, and to compare the results of the two registrations. They are induced to hope that at the next meeting of the Association they shall be enabled to lay before it a considerable accumulation of results obtained by trials of the instrument under a variety of different circumstances, and, in the confidence of the principles on which its construction is founded and of these results, to present it to the Association as a permanent indicator registering with certainty the work done upon the piston of a steam-engine under every circumstance of motion and effort.

PROVISIONAL REPORTS, AND NOTICES OF PROGRESS IN SPECIAL RESEARCHES ENTRUSTED TO COMMITTEES AND INDIVIDUALS..

Report of the Committee on the Forms of Vessels. By J. S. Russell.

Mr. Scott Russell reported the progress made by "the Committee on Forms of Vessels" during the past year. The object of the experiments is twofold; to advance our knowledge of the laws of resistance of fluids, and to obtain data for the practical improvement of the art of naval construction.

Many and expensive are the experiments formerly made on this subject. Unfortunately these experiments have been made with imperfect apparatus, or under circumstances different from the conditions of bodies moving on the surface of the water, or on solids of a form unsuitable to the formation of ships, or on so small a scale as to render them unworthy of the confidence of the practical constructor. In the present series of experiments a more simple apparatus was employed than on any former occasion. The forms of body experimented upon were those of actual ships, or bodies analogous to those in use; it being the object of the experiments to supply the actual desiderata of hydrodynamics and of practical ship-building. The experiments were made on vessels of every size, from models of 30 inches in length to vessels of 1300 tons. The experiments were also made upon vessels in water of variable depth, and in channels of various dimensions, so as, if possible, to embrace all the elements of the resistance. A minute description of some of the apparatus was then given along with some general illustrations; but as the experiments were still in progress, and to be continued during the following year, no general statement of results was entered into. It was expected that by next meeting the whole would be concluded.

Report of the Committee on Waves. By J. S. Russell.

At the last meeting some discussions had taken place, tending to show the value of an accurate determination of the velocity of the great wave of translation in a channel of triangular section. Some other subjects, demanding additional experiments, had also occurred to Mr. Russell since last meeting, and an apparatus capable of generating large waves in a large triangular channel had been constructed. The point to be determined, regarding the velocity of the great primary wave in the channel of triangular section, was this,—whether the velocity were that which is due by gravity to a depth of one-fourth part of the depth of the channel, or of one-third. The difficulty of this determination arises from several causes: first of all, the wave in the triangular section had a less continuous form than in the rectangular channel; and, secondly, the portion of fluid in the angle of the channel at the bottom does not acquire the same motion of translation with the remainder of the fluid in the wider parts of the channel. These causes tend to retard the motion, and to render it matter of doubt whether the actual velocity approaches nearer to that due to one-third or one-fourth of the depth. An example of the results obtained by experiment is as follows:—

The velocity due to one-third of the depth being ... 6·5 feet per sec.
The velocity due to one-fourth of the depth being... 5·7 feet per sec.
The velocity observed by experiment was .... 6·3 feet per sec.

The general conclusion being, that the velocity of the great primary wave of translation in a triangular channel is nearly that due to one-third of the depth, making allowance for the resistance of the small portion in the angle of the bottom, the result being nearer to the velocity due to one-third than to one-fourth of the depth. The next point investigated was a curious phænomenon to which Mr. Russell had given the designation of the "great negative wave." This phænomenon was in some respects the counterpart of the great wave of translation. It has this curious property, that instead of being propagated across other waves as the common oscillatory waves are, both in their positive and negative portions, this negative wave and the positive wave, when meeting, had the effect of neutralizing each other so perfectly, as altogether to leave the fluid in a state of rest, with the exception only of certain residual oscillatory waves of the second order. With this wave a number of curious phænomena were associated, and it appeared to form an important element in the resistance of fluids to the posterior portion of a ship, while the positive wave was closely associated with the resistance to the anterior part. A series of experiments had also been made on a point which had not previously been examined,—the influence of the velocity of the wave on the resistance of a fluid to bodies moving with velocities remote from the velocity of the wave; whether, when a body moves with a *given* velocity *less* than that of the wave, it will be more or less resisted according as the velocity of the wave is more remote or less remote from its own; and whether, when a body moves with a *given* velocity *greater* than that of the wave, it will experience more or less resistance, according as the velocity of the wave is more or less remote from its own. The general result is, that with velocities less than that of the wave, the resistance increases in a certain manner as the velocity of the wave diminishes, and that in velocities greater than that of the wave, the resistance diminishes as the velocity of the wave diminishes. Slowness of motion of the wave, while it is least favourable to low velocities, is most favourable to high velocities; hence rectangular canals are best for low velocities, and sloping sides for high velocities.

Report by the Committee to the British Association for the Advancement of Science, appointed to superintend the Engraving of Skeleton Maps for recording the Distribution of Plants and Animals.

YOUR Committee, to whom an additional grant of 25*l.* was entrusted last year for the above purpose, beg to report that as yet only a small part of that grant has been applied, and they do not therefore require to draw for any sum till next year, by which time they expect to see the maps, already engraved, applied *practically* for carrying out the object in view.

To explain why this has not been already done, they may state that Mr. Brand (one of their number), to whom, as before, the execution of the design was principally committed, and who last year had sent copies of the maps, with documents illustrative of their application (as proposed by the Botanical Society of Edinburgh), to various scientific gentlemen, whose opinion it was thought desirable to obtain before circulating them more extensively, has been since that time in communication with several of those gentlemen, from whom he has received useful suggestions, although on a few points their views do not entirely coincide. Effect has already been given to some objections stated by them, and others have been removed by satisfactory explanations; so that now there are no important differences remaining. Mr. Brand is therefore prepared immediately to recommence his labours, by revising carefully the whole details, and making such improvements as the suggestions transmitted to him and his own more mature opinions shall dictate.

When this revision shall have been completed, the maps, &c. will be again laid before the other members of the Committee for their final sanction, and thereafter it is proposed to transmit copies of the whole to scientific gentlemen both at home and abroad, partly with the view of disseminating, as widely as possible, a knowledge of the scheme, and partly to obtain further observations from competent parties, before any great progress has been made in its application for the intended purposes.

In the meantime a copy of the maps, and illustrative documents above mentioned, as they now stand, are sent herewith, and a further impression of both has been thrown off, and forwarded to Plymouth for distribution among such members of the Association as may take an interest in this subject; so that the Committee hope soon to be prepared with a more particular statement of their proceedings, as well as of the advantages which may be expected to result from this design itself, so liberally encouraged by the Association.

They therefore beg leave to propose that the grant, voted in September last, be continued till next annual meeting.

ROBERT GRAHAM, *Chairman of Committee.*

Edinburgh, July 24, 1841.

Report of the Committee for the Reduction of Lacaille's Stars in the Cœlum Australe Stelliferum.

YOUR Committee have to report that the Observations are reduced, the whole of the computations executed, and the arranged catalogue completed and delivered to Mr. Baily, to be employed in the construction of the extended edition of the Catalogue of the Astronomical Society. The expense has been much less than was anticipated. The exact sum will be reported officially by the Treasurer; but after defraying the further expenses incurred for computation labour, 76*l.* 15*s.*, and somewhere about 3*l.* for postage and stationery, a sum of about 100*l.* of the original grant will be found to remain unappropriated, and will not be required for the purpose for which the Committee was appointed.

Signed, J. F. W. Herschel, on the part of the Committee.

Report of the Astronomer Royal on the publication of the Hourly Observations made at Plymouth, under the superintendence of Mr. W. S. Harris.

1. The first series of observations of the thermometer extends from May 1832, to December 1836, containing readings of the thermometer for every hour of the day and night. The means of the readings are taken for each day; and for each hour the means for groups of ten or eleven days are taken. —2. The second series of observations of the thermometer extends from January 1837 to December 1839, and contains readings of the wet and dry thermometer for every hour of the day and night. The means of the readings are taken for each day.—3. The observations of the barometer extend from January 1837 to December 1839, and contain readings of the barometer and attached thermometer for every hour of the day and night. The means are taken for each day.

I am not aware that there exists any such collection of regular, consecutive, and uniform observations. But I must beg that this, my statement, be received with caution, for the two following reasons: first, that I am little acquainted with the current literature of Meteorology; secondly, that I know nothing whatever of Mr. Harris's instruments, and especially, that I have no assurance either of the identity of the instruments through the series, or of the verification of their zero points; two matters of capital importance. Assuming, however, that the instruments have been the same, and properly verified, I have no hesitation in recommending that the observations be printed in full. And (considering that many of the purposes to which they may at future times be applied are yet unknown) I do not see that any further deduction should be drawn, in the printed arrangement, than is drawn by Mr. Harris, except that I would submit for Mr. Harris's consideration, whether the means of the observations of several days, at the same hour, should not be taken for the second and third series, in the same manner as for the first.

G. B. Airy.

On the Translation of Foreign Scientific Memoirs.

The Committee have received in the current year translations of the following memoirs, presented to the Committee for the purpose of insertion in Mr. Taylor's collection of "Foreign Scientific Memoirs," viz.

From Professor Thomas Graham—

Redtenbacher on the Composition of the Stearic Acid.

Provostaye on the Action of Sulphurous Acid on Hyponitric Acid, and on the Theory of the formation of Sulphuric Acid.

From Sir William Jardine, Bart.—

Bischoff on the Anatomy of the Lepidosiren.

Müller on the Anatomy of Myxine, &c.

From Lieut-Colonel Sabine—

Gauss on a Method of facilitating the Observations of Deflection.

Gauss on the Laws of the Mutual Action of Bodies whose elements attract or repel in the inverse ratio of the square of the distance.

These memoirs have been given to Mr. Richard Taylor.

The only expenditure which has been made from the grant placed at the disposal of the Committee for the current year has been 11*l.* 2*s.* for a plate of the Transportable Magnetometer lithographed at Göttingen under the direction of M. Weber, the inventor of the Sextant, and admitted duty-free by permission of the Lords Commissioners of the Treasury.

(Signed on the part of the Committee) EDWARD SABINE.

Report on the Hourly Observations at Inverness and Uist.

IN conformity with the wishes of the British Association, the Hourly Observations at Inverness were recommenced on the 1st of November 1840; but a difficulty presented itself to their renewal at Kingussie, which it was not easy to overcome.

Under these circumstances, I felt that I should promote in the most effectual manner the objects which the Association contemplated, by transferring the observations to a more northern locality; and, with the assistance of Dr. Fleming, I succeeded in establishing them at Balta Sound in Unst, the most northern of the Shetland Islands, already distinguished in the history of science by the astronomical observations made there in 1817 and 1818 by M. Biot and Captain Kater.

Dr. Edmonston of Buness, whose love of science induced him to enter warmly into the views of the Association, undertook to superintend the observations, which were begun early in the present year.

The island of *Unst* being situated in lat. 60° 40′, Leith in lat. 55° 58′, and Plymouth in lat. 50° 22′, and all of them nearly in the same meridian, we shall now obtain a series of hourly observations of peculiar value, from their being made at the extremities and the middle of an arch of the meridian of more than ten degrees. D. BREWSTER.

St. Leonard's, St. Andrew's, July 28, 1841.

Report on the Erection of an Osler's Anemometer at Inverness.

THE Anemometer constructed by Mr. Osler for Inverness, though ready for use, has not yet been erected, in consequence of an unexpected difficulty in finding a suitable building.

It was at first proposed to erect it on the roof of Raining's school, where the hourly meteorological observations are made by Mr. Mackenzie; but the roof of this building was not considered strong enough for the purpose, and other difficulties prevented this arrangement from being carried into effect.

The observatory of Inverness was unfortunately in the act of being transferred from one body of proprietors to another, otherwise the anemometer would have been erected on its summit; but I am informed by Mr. Mackenzie that the transaction is nearly completed, and that the Committee of the Mechanics' Institute, to whom it now belongs, will cheerfully devote a part of it for the reception of the anemometer. D. BREWSTER.

St. Leonard's, St. Andrew's, July 22, 1841.

Report on the State of the Inquiry into the Action of Gaseous and other Media on the Solar Spectrum.

IN prosecuting this inquiry my attention has been principally directed to the action of the earth's atmosphere upon the solar spectrum, and I hope to be able to present to the next meeting of the Association a map of the bands produced by atmospheric absorption. I have also made considerable progress in constructing a map of the spectrum, containing the numerous lines and bands produced by the action of nitrous gas.

In submitting to examination several other gaseous media, my results have been principally of a negative character; but in my experiments with solid and fluid media, I have been led to positive and interesting results.

In order to obtain additional accuracy of observation, particularly near the extremities of the spectrum, Mr. Dollond has constructed for me some important pieces of apparatus for directing and condensing the solar rays; and I have recently obtained from Mr. Merz of Munich, a very large prism, to be used with the telescope, and a series of smaller prisms for constructing a prismatic cylinder for the purpose of expanding or magnifying particular parts of the spectrum. D. BREWSTER.

St. Leonard's, St. Andrew's, July 26th, 1841.

THE *Committee appointed to superintend the reduction of the stars in the Histoire Céleste*, report—

That, at the last meeting of the British Association, they stated that it would cost about 200*l.* more than the sum *then* expended, to complete the whole of the reductions. That some error appears to have taken place in the amount of the grant, as only 150*l.* was appropriated, of which 135*l.* has now been expended, thus leaving 15*l.* in hand. The Committee, therefore, again suggest the propriety of extending the grant, this year, to 65*l.*, which will complete the original estimate for the whole of the reductions, and which can thus be finished before the next meeting of the Association.

FRANCIS BAILY.

THE *Committee appointed to superintend the extension of stars in the Royal Astronomical Society's Catalogue*, report—

That no delay has taken place in prosecuting the work, and that it is expected to be completed in a short time. That 40*l.* has been expended out of the 150*l.* granted at the last meeting of the British Association; and consequently that there is 110*l.* still in abeyance, which the Committee request may be continued till the completion of the work, in order to meet any contingent expenses. FRANCIS BAILY.

On the subject of Researches concerning the Mud of Rivers, the following notice has been received from Mr. J. BRYCE, Jun.

Maghera, County of Londonderry, July 19, 1841.

I HAVE received from the Treasurer 5*l.* of the grant, of which I have expended about 1*l.* in commencing the inquiry; but owing to the construction of a coffer dam, and other obstructions in the river at Belfast, preparatory to the erection of a new bridge, I have not yet been able to obtain any result which would be worth communicating to the Association. If, however, the grant be renewed, I shall continue my inquiries vigorously after my return to Belfast, during the autumn and winter.

Nothing has been done by the other members of the Committee, as I retain possession of the vessel which we use for raising the water.

I am, dear Sir, faithfully yours,

JAMES BRYCE, Jun.

Report of the Committee on Marine Zoology.

THEY have expended in dredging on the coast of the county of Antrim the sum of 25*s*., but were obliged, by the tempestuous state of the weather and other causes, to suspend further operations. They recommend that a renewal of the grant of 50*l*. be applied for.

ROBERT PATTERSON,
R. BALL.

Notices of progress have been received in regard to the *Report on Caprimulgidæ*, by Mr. Gould; *on Ornithology*, by Mr. Selby; *on Radiata*, by Sir J. G. Dalyell.

Sir W. Jardine reported that the inquiry formerly entrusted to him regarding the *Salmonidæ* of Scotland is still in progress.

Sir W. Jardine, on behalf of the Committee appointed to take steps for increasing our knowledge of the *Anoplura Britanniæ*, reported that by the encouragement afforded by the Committee to Mr. Denny, who has been long and diligently engaged in this branch of Natural History, that gentleman has been enabled to make arrangements for the speedy publication of a work on the subject, illustrated with coloured plates, twenty-one of which have been submitted to the inspection of the Committee.

Dr. Buckland, on behalf of a Committee who were instructed to take steps for augmenting our knowledge of the fossil fishes of the Old Red Sandstone of Great Britain, states, that owing to the severe illness of M. Agassiz, whose assistance the Committee had secured, no report can at present be drawn up.

Dr. Buckland, on behalf of a Committee appointed to procure coloured drawings of the Sections of Strata exposed in Railway excavations, made the following statement.

"July 13, 1841.

"I have to report that a plate has been engraved from a pattern Section prepared by Mr. Phillips, and that several hundred impressions from this plate have been circulated among Civil Engineers, who have kindly promised to assist in procuring the information we wish to obtain; but that the only Sections yet received have been prepared by W. Sanders, Esq. from the Great Western Railroad near Bristol; and Mr. Craig, of the Glasgow and Ayr, and Glasgow and Greenock Railways."

VARIETIES OF HUMAN RACE.

Queries respecting the Human Race, to be addressed to Travellers and others. Drawn up by a Committee of the British Association for the Advancement of Science, appointed in 1839.

[Referred to present vol. of Reports, p. 52.]

AT the meeting of the British Association held at Birmingham, Dr. Prichard read a paper "On the Extinction of some varieties of the Human Race." He pointed out instances in which this extinction had already taken place to a great extent, and showed that many races now existing are likely, at no distant period, to be annihilated. He pointed out the irretrievable loss which science must sustain, if so large a portion of the human race, counting by tribes instead of individuals, is suffered to perish, before many interesting questions of a psychological, physiological and philological character, as well as many historical facts in relation to them, have been investigated. Whence he argued that science, as well as humanity, is interested in the efforts which are made to rescue them, and to preserve from oblivion many important details connected with them.

At the suggestion of the Natural Historical Section, to which Dr. Prichard's paper was read, the Association voted the sum of £5 to be expended in printing a set of queries to be addressed to those who may travel or reside in parts of the globe inhabited by the threatened races. A Committee was likewise appointed by the same Section to prepare a list of such questions. The following pages, to which the attention of travellers and others is earnestly invited, have, in consequence, been produced. It is right to observe, that whilst these questions have been in preparation, the Ethnographical Society of Paris has printed a set of questions on the same subject for the use of travellers. It has been gratifying to perceive the general similarity between the questions proposed by the French savans who compose that Society, and those which had been already prepared by the Committee; but the Committee is bound to acknowledge the assistance which, in the completion of its task, it has derived from the comprehensive character and general arrangement of the Ethnographical Society's list. The following queries might have been considerably extended, and much might have been added to explain the reasons and motives on which some of them are founded. Such additions would, however, have inconveniently extended these pages, and, in part, have defeated their object. The Committee has only further to express its desire that the Association may continue its support to the interesting subject of Ethnography, and that their fellow-members will aid in bringing these queries under the notice of those who may have it in their power to obtain replies. Britain, in her extensive colonial possessions and commerce, and in the number and intelligence of her naval officers, possesses unrivalled facilities for the elucidation of the whole subject; and it would be a stain on her character, as well as a loss to humanity, were she to allow herself to be left behind by other nations in this inquiry.

It will be desirable, before giving direct answers to the questions proposed in the following list, that the traveller should offer, in his own terms, a description of the particular group of human beings, which he may have in view in drawing up his list of answers, seeing that the replies, however accurate and replete with useful information, may fail in some particulars to give a complete idea of the people to whom they relate.

Physical Characters.—1. State the general stature of the people, and confirm this by some actual measurements. Measurement may be applied to absolute height, and also to proportions, to be referred to in subsequent queries. The weight of individuals, when ascertainable, and extreme cases, as well as the average, will be interesting. What may be the relative differences in stature and dimensions, between males and females?

2. Is there any prevailing disproportion between different parts of the body? as, for example, in the size of the head, the deficient or excessive development of upper or lower extremities.

3. What is the prevailing complexion? This should be accurately defined, if possible, by illustrative and intelligent example, such as by comparison with those whose colour is well known. The colour of the hair should be stated, and its character, whether fine or coarse, straight, curled, or woolly. The colour and character of the eyes should likewise be described. Is there, independently of want of cleanliness, any perceptible peculiarity of odour?

4. The head is so important as distinctive of race, that particular attention must be paid to it. Is it round or elongated in either direction, and what is the shape of the face, broad, oval, lozenge-shaped, or of any other marked form? It will contribute to facilitate the understanding of other descriptions, to have sketches of several typical specimens. A profile, and also a front view should be given. In the profile, particularly notice the height and angle of the forehead, the situation of the meatus auditorius, and the form of the posterior part of the head. It will also be desirable to depict the external ear, so as to convey the form and proportion of its several parts. The form of the head may be minutely and accurately described by employing the divisions and terms introduced by craniologists, and the corresponding development of moral and intellectual character should in conjunction be faithfully stated. So much of the neck should be given with the profile as to show the setting on of the head. The advance or recession of the chin, and the character of the lips and nose, may likewise be given in profile. The front view should exhibit the width of forehead, temples, and cheek-bones, the direction of the eyes, and the width between them: the dimensions of the mouth. When skulls can be collected or examined, it would be desirable to give a view in another direction, which may even be done, though with less accuracy, from the living subject. It should be taken by looking down upon the head from above, so as to give an idea of the contour of the forehead, and the width of the skull across from one parietal protuberance to the other.

5. State whether the bones of the skull are thick, thin, heavy, or light. Is it common to find the frontal bone divided by a middle suture or not? Note the form of the outer orbitar process, which sometimes forms part of a broad scalene triangle, with the vertex downwards. How are the frontal sinuses developed? Observe whether the ossa triquetra are frequent, or otherwise; whether there be frequent separation of the upper part of the os occipitis; the relative situation of the foramen magnum. In regard to the bones of the face, notice the position of the ossa nasi and unguis; the former sometimes meet nearly or quite on the same plane, whilst, in others, they meet at an angle. The former character is strongly marked in many African skulls. State the form of the jaw bone, shape of the chin, and observe the angle of the jaw, the position and character of the teeth, and their mode of wear; and if they have any practice of modifying their form or appearance, let this be stated. The malar bones have already been noticed, but they may require a more minute description.

6. When the opportunity can be found, observe the number of lumbar vertebræ, since an additional one is said to be common in some tribes.

7. Give the length of the sternum as compared with the whole trunk; and

also some idea of the relative proportion between the chest and the abdomen.

8. What is the character of the pelvis in both sexes, and what is the form of the foot?

9. The form of the scapula will also deserve attention, more especially as regards its breadth and strength; and the strength or weakness of the clavicle should be noticed in connexion with it.

10. The internal organs, and blood-vessels, will with greater difficulty be subjected to examination; but it may be well here to remark, that varieties in these may prevail locally in connexion with race.

N.B.—Peculiarities may exist, which cannot be anticipated in queries, but which the observer will do well to notice amongst his answers to anatomical questions.

11. Where a district obviously possesses two or more varieties of the human race, note the typical characters of each in their most distinct form, and indicate to what known groups or families they may belong: give some idea of the proportion of each, and state the result of their intermixture on physical and moral character. When it can be ascertained, state how long intermixture has existed, and of which the physical characters tend to predominate. It is to be observed, that this question does not so much refer to the numerical strength or political ascendency of any of the types, but to the greater or less physical resemblance which the offspring may bear to the parents, and what are the characters which they may appear to derive from each: whether there is a marked difference arising from the father or the mother belonging to one of the types in preference to another; also whether the mixed form resulting from such intermarriage is known to possess a permanent character, or after a certain number of generations to incline to one or other of its component types.

12. Any observation connected with these intermarriages, relating to health, longevity, physical and intellectual character, will be particularly interesting, as bringing light on a field hitherto but little systematically investigated. Even when the people appear to be nearly or quite free from intermixture, their habits, in respect of intermarriage within larger or smaller circles, and the corresponding physical characters of the people, will be very interesting.

Language.—13. Do the natives speak a language already known to philologists, and if so, state what it is; and notice whether it exhibit any dialectic peculiarities, as well as the modifications of pronunciation and accentuation which it may offer. State also the extent to which this dialect may be used, if limits can be ascertained.

14. If the language be little if at all known, endeavour to obtain a vocabulary as extensive as circumstances will allow, and at least consisting of the numerals, the most common and important substantives*, the pronouns in all persons and numbers, adjectives expressive of the commonest qualities, and, if possible, a few verbs varied in time and person. The vocabulary should be tested by the interrogation of different natives, and more than one person should be engaged in taking it down from their mouths, to avoid, as far as may be, errors arising from peculiarities of utterance or defect of hearing. It is likewise of importance that the system of orthography be duly indicated and strictly adhered to.

15. Endeavour to take down some piece of native composition, such as the ordinary phrases employed in conversation, and any other piece of prose which may be attainable; and specimens of metrical composition if such Though these would be of comparatively little use without transla-

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* The names of mountains, lakes, rivers, islands, &c.

tion, yet independently of this some importance is to be attached to the metrical compositions if they have a national character and are widely diffused; and, in this case, it might be possible to express some of their airs in musical characters. A specimen of known composition translated into their language, may also be given, such as the first chapter of Genesis, the fifteenth chapter of Luke's Gospel, and the Lord's Prayer.

16. Endeavour to ascertain whether the language is extensively spoken or understood, and whether there are different languages spoken by men having similar physical characters obviously connecting them as a race, or if differing somewhat in this respect, inhabiting a particular geographical tract. When such groups are said to possess different languages, endeavour, as far as possible, to ascertain their number, the sources whence each is derived, and the languages to which it is allied; and also the circumstances, geographical or political, which may account for these distinctions.

[For further information connected with the investigation of languages, reference is made to a short essay on this subject read to the Philological Society of London.]

Individual and Family Life.—17. Are there any ceremonies connected with the birth of a child? Is there any difference whether the child be male or female?

18. Does infanticide occur to any considerable extent, and if it does, to what causes is it to be referred, want of affection, deficient subsistence, or superstition?

19. Are children exposed, and from what causes, whether superstition, want of subsistence or other difficulties, or from deformity, general infirmity, or other causes of aversion?

20. What is the practice as to dressing and cradling children, and are there any circumstances connected with it calculated to modify their form; for example, to compress the forehead, as amongst the western Americans; to flatten the occiput, as amongst most Americans, by the flat straight board to which the child is attached; to occasion the lateral distortion of the head, by allowing it to remain too long in one position on the hand of the nurse, as amongst the inhabitants of the South Seas?

21. Are there any methods adopted, by which other parts of the body may be affected, such as the turning in of the toes, as amongst the North Americans; the modification of the whole foot, as amongst the Chinese?

22. How are the children educated, what are they taught, and are there any methods adopted to modify their character, such as to implant courage, impatience of control, endurance of pain and privation, or, on the contrary, submission, and to what authorities, cowardice, artifice?

23. Is there anything remarkable amongst the sports and amusements of children, or in their infantile songs or tales?

24. At what age does puberty take place?

25. What is the ordinary size of families, and are there any large ones?

26. Are births of more than one child common? What is the proportion of the sexes at birth and among adults?

27. Are the children easily reared?

28. Is there any remarkable deficiency or perfection in any of the senses? It is stated, that in some races sight is remarkably keen, both for near and distant objects.

29. To what age do the females continue to bear children? and for what period are they in the habit of suckling them?

30. What is the menstrual period, and what the time of utero-gestation?

31. Are there any ceremonies connected with any particular period of life?

32. Is chastity cultivated, or is it remarkably defective, and are there any classes amongst the people of either sex by whom it is remarkably cultivated, or the reverse, either generally or on particular occasions?

33. Are there any superstitions connected with this subject?

34. What are the ceremonies and practices connected with marriage?

35. Is polygamy permitted and practised, and to what extent?

36. Is divorce tolerated, or frequent?

37. How are widows treated?

38. What is the prevailing food of the people? Is it chiefly animal or vegetable, and whence is it derived in the two kingdoms? Do they trust to what the bounty of nature provides, or have they means of modifying or controlling production, either in the cultivation of vegetables, or the rearing of animals? Describe their modes of cooking, and state the kinds of condiment which may be employed. Do they reject any kinds of aliment from scruple, or an idea of uncleanness? Have they in use any kind of fermented or other form of exhilarating liquor, and, if so, how is it obtained? What number of meals do they make? and what is their capacity for temporary or sustained exertion?

39. Describe the kind of dress worn by the people, and the materials employed in its formation. What are the differences in the usages of the sexes in this respect? Are there special dresses used for great occasions? and, if so, describe these, and their modes of ornament. Does any practice of tattooing, piercing, or otherwise modifying the person for the sake of ornament, prevail amongst the people? N.B. Such modifications not to be blended with other modifications used as signs of mourning, &c.

40. Have the people any prevailing characteristic or remarkable modes of amusement, such as dances and games exhibiting agility, strength or skill?

41. Are games of chance known to the people, and is there a strong passion for them?

42. Do the people appear to be long or short-lived? If any cases of extreme old age can be ascertained, please to state them. Such cases may sometimes be successfully ascertained by reference to known events, as the previous visits of Europeans to the country. Is there a marked difference between the sexes in respect of longevity?

43. What is the general treatment of the sick? Are they cared for, or neglected? Are any diseases dreaded as contagious, and how are such treated? Is there any medical treatment adopted? Are there any superstitious or magical practices connected with the treatment of the sick? What are the most prevailing forms of disease, whence derived, and to what extent? Is there any endemic affection, such as goitre, pelagra, plica, or the like? With what circumstances, situations, and habits do they appear to be connected, and to what are they referred by the people themselves?

44. Where there are inferior animals associated with man, do they exhibit any corresponding liability to, or exemption from disease?

45. Do entozoa prevail, and of what kind?

46. What is the method adopted for the disposal of the dead? Is it generally adhered to, or subject to variation?

47. Are any implements, articles of clothing, or food, deposited with the dead?

48. Is there any subsequent visitation of the dead, whether they are disposed of separately, or in conjunction with other bodies?

49. What is the received idea respecting a future state? Does this bear the character of transmigration, invisible existence about their accustomed haunts, or removal to a distant abode?

Buildings and Monuments.—50. What are the kinds of habitations in use among the people? Are they permanent or fixed? Do they consist of a single apartment, or of several? Are the dwellings collected into villages or towns, or are they scattered, and nearly or quite single? If the former, describe any arrangement of them in streets or otherwise which may be employed.

51. Have any monuments been raised by the present inhabitants or their predecessors, and more especially such as relate to religion or war? State their character, materials, and construction. If they are still in use amongst the people, state this object, even if they should be of the simplest construction, and be little more than mounds or tumuli. If these monuments are no longer in use, collect, as far as possible, the ideas and traditions of the natives regarding them, and, if possible, have them examined by excavation or otherwise, taking care to deface and disturb them as little as possible.

52. In these researches be on the look out for the remains of the skeletons of man or other animals, and, if discovered, let them be preserved for comparison with those still in existence.

Works of Art.—53. Let works of art, in metal, bone, or other materials, be likewise sought and preserved, and their similarity to, or difference from implements at present in use amongst the people of the district, or elsewhere, be noted.

54. When a people display their ingenuity by the extent or variety of their works of art, it will not only be desirable to describe what these are, but also the materials of which they are constructed, the modes in which these materials are obtained, the preparation which they undergo when any is required, and the instruments by which they are wrought. Such particulars will not only throw light on the character and origin of the people, but will, directly or indirectly, influence the commercial relations which may be profitably entered into when commerce alone is looked to. When colonization is contemplated, the facts contained in the replies to these queries will point out the mntual advantages which might be obtained by preserving, instead of annihilating, the aboriginal population.

Domestic Animals.—Are there any domestic animals in the possession of the people? Of what species are they? Whence do they appear to have been derived, and to what variety do they belong? Have they degenerated or become otherwise modified? To what uses are they applied?

Government and Laws.—55. What is the form of government? Does it assume a monarchical or democratic character, or does it rest with the priests?

56. Are the chiefs, whether of limited or absolute power, elective or hereditary?

57. Is there any division of clans or castes?

58. What are the privileges enjoyed by or withheld from these?

59. What care is taken to keep them distinct, and with what effect on the physical and moral character of each?

60. What laws exist among the people? How are they preserved? Are they generally known, or confided to the memory of a chosen set of persons? What are their opinions and regulations in reference to property, and especially the occupation and possession of the soil? Does the practice of hiring labourers exist among them?

61. Have they any knowledge or tradition of a legislator, to whom the formation of laws is ascribed?

62. Do they rescind, add to, or modify their laws? and how?

63. Are they careful in the observance of them?

64. What are their modes of enforcing obedience, and of proving and punishing delinquency?

65. How are judges constituted? Do their trials take place at stated periods, and in public?

66. How do they keep prisoners in custody, and treat them?

67. What are the crimes taken cognizance of by the laws? Is there gradation or commutation of punishment?

Geography and Statistics.—68. Briefly state the geographical limits and character of the region inhabited by the people to whom the replies relate.

69. State approximatively the number of inhabitants. As this is an important, but very difficult question, it may not be amiss to point out the modes in which the numbers may be ascertained. The people themselves may state their number with more or less accuracy, but it should be known whether they refer to all ranks and ages, or merely comprehend adult males, who may be mustered for war, or other general purpose requiring their combination. In this case state the apparent proportion between adult males and other members of families. The number of habitations in a particular settlement may be counted, and some idea of the average numbers of a family be given. Where the people inhabit the water-side, the number and dimensions of their craft may be taken, and some idea of the proportion between the number of these and of the individuals belonging to them, may be formed. In drawing conclusions from observations of this kind, it will be necessary to have due regard to the different degrees of density or rarity in which, from various causes, population may be placed.

70. Has the number of inhabitants sensibly varied, and within what period?

71. If it have diminished, state the causes; such as sickness, starvation, war, and emigration. When these causes require explanation, please to give it. If the inhabitants are on the increase, is this the result of the easy and favourable circumstances of the people causing an excess of births over deaths; or is it to be assigned to any cause tending to bring accessions from other quarters? State whether such causes are of long standing, or recent.

72. Is the population generally living in a manner to which they have been long accustomed, or have new relations with other people, and consequently new customs and practices, been introduced?

73. If the people, being uncivilized, have come under the influence of the civilized, state to what people the latter belong, how they are regarded, and what is the kind of influence they are producing*. State the points of their good influence, if any, and those of an opposite character, as the introduction of diseases, vices, wars, want of independence, &c.

74. Is there any tendency to the union of races? how is it exhibited, and to what extent?

Social Relations.—75. What kind of relationship, by written treaty or otherwise, subsists between the nation and other nations, civilized or not? Have they any intercourse by sea with other countries? Do any of them understand any European language? Or are there interpreters, by whom they can communicate with them?

76. Are they peaceable, or addicted to war? Have they any forms of declaring war, or making peace? What is their mode of warfare, either by sea or land? their weapons and strategy? What do they do with the slain, and with prisoners? Have they any mode of commemorating victories by monuments, hieroglyphics, or preservation of individual trophies, and of what kind? Have they any national poems, sagas, or traditions respecting their origin and history? Where Europeans have introduced fire-arms, ascertain the modes of warfare which have given place to them.

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* This question will comprise the existence of missions—the success or the want of it from causes connected with missionaries themselves or others.

State whatever particulars, respecting their origin and history, are derived either from traditions among themselves or from other sources.

Religion, *Superstitions*, *&c.*—77. Are the people addicted to religious observances, or generally regardless of them?

78. Do they adopt the idea of one great and presiding Spirit, or are they polytheists?

79. If polytheism exist, what are the names, attributes, and fables connected with their deities, and what are the modes in which devotion is paid to each? Are any parts of the body held sacred, or the reverse? Do they offer sacrifices, and are they of an expiatory character, or mere gifts?

80. Have they any sacred days or periods? fixed or moveable feasts, or religious ceremonies of any kind, or any form of thanksgiving or other observance connected with seasons?

81. Have they any order of priests, and if so, are they hereditary, elective, or determined by any particular circumstance?

82. Is the religion of the people similar to that of any other people, neighbouring or remote? If different, are they widely so, or dependent on particular modifications, and of what kind?

83. In what light do they regard the religion and deities of neighbouring tribes?

84. Is there any idea of an inferior order of spirits and imaginary beings,—such as ghosts, fairies, brownies, and goblins; and how are they described?

85. Have they any notions of magic, witchcraft, or second sight?

86. What ideas are entertained respecting the heavenly bodies? Have they any distinction of stars, or constellations? and if so, what names do they give them, and what do these names signify?

87. Are they in any manner observed with reference to the division of the year, and how?

88. If time is not divided by observations of those bodies, what other mode is adopted? and do observances connected with them rest with the priests or chiefs?

89. When the traveller, by personal acquaintance with the language, or by means of competent assistance from interpreters, can freely converse with the people, it will be desirable that he should form some idea of their amount of intelligence, their tone of mind with regard to social relations, as respects freedom, independence, or subserviency, and their recognition of moral obligations, and any other psychological character which observation may detect; and more especially such as may contribute to an estimation of the probable results of efforts to develope and improve the character.

Observations made at the Magnetic Observatory at Toronto, during a remarkable Magnetic Disturbance on the 25th and 26th of September, 1841; *with Postscripts, containing the Observations of the same Disturbance made at the Magnetic Observatories of Trevandrum, St. Helena, and the Cape of Good Hope.*

THE interest which Mr. Airy's Circular Letter has excited on the subject of the magnetical disturbance, which was observed at Greenwich on the 25th of September last, makes it probable that considerable advantage may be derived, by immediate publicity being given to the observations which were made on the same day at the Magnetical Observatory at Toronto in Canada, showing the effects of the same disturbance in America.

In the regular course of the publication, proceeding under the direction and at the expense of Government, of the observations made at the Magnetical Observatories conducted by officers of the Royal Artillery, several months would necessarily elapse before the observations of September 25, 1841, would pass through the press. Under these circumstances, the MASTER-GENERAL of the ORDNANCE has approved of their immediate publication in a separate form, which will enable them to be communicated at once to the Directors of similar establishments in all parts of the globe; and the Committee of the BRITISH ASSOCIATION, appointed to conduct the co-operation of that body in the system of simultaneous magnetical and meteorological observations, have deemed this a fitting occasion for the employment of a portion of the grant placed at their disposal.

The abstracts received from the Observatory contain the observations expressed in the scale-divisions in which they are read: these have been converted by Lieut. Riddell, R.A., both in the tables and plate, into the more convenient forms,—of angular value for the declination,—and for the horizontal and vertical force, of the proportion which the changes of those forces bear to their whole amount. The plate also shows the mean daily curve of each element during the month of September, the comparison of which with the curve on the 25th affords a measure of the magnetic disturbance on that day, both being reduced to the same Zeros.

The perseverance with which the magnetometers were followed during twenty hours, by observations taken at intervals of a minute and a half, is highly creditable to Lieut. Younghusband and his detachment.

EDWARD SABINE, Lieut.-Col. R.A.

Woolwich, Dec. 10, 1841.

OBSERVATORY AT TORONTO, CANADA.

Abstract of Observations taken during a remarkable disturbance on the 25th and 26th September, 1841.

Declination-Magnetometer.

	Gött. Mean Time.	$0^m\ 0^s$	$5^m\ 0^s$	$10^m\ 0^s$	$15^m\ 0^s$	$20^m\ 0^s$	$25^m\ 0^s$	$30^m\ 0^s$	$35^m\ 0^s$	$40^m\ 0^s$	$45^m\ 0^s$	$50^m\ 0^s$	$55^m\ 0^s$
25	10 A.M.	60′·3	′ ...	′ ...	′ ...	65′·0	65′·0	61′·9	57′·8	59′·2	59′·9	60′·5	50′·9
	11 „	50·8	31·2	32·6	34·0	35·9	37·7	43·3	42·3	40·6	39·2	45·9	44·0
	12 „	41·3	38·7	37·6	32·7	26·5	30·4	30·0	30·5	28·8	28·6	29·6	26·1
	1 P.M.	18·8	18·1	23·0	29·4	30·2	26·5	18·1	17·2	12·5	11·7	8·9	12·8
	2 „	21·5	25·7	23·5	22·5	22·8	21·5	18·9	22·5	22·7	22·8	25·9	24·8
	3 „	24·8	9·2	10·4	9·7	4·7	7·8	17·7	18·9	21·2	12·7	15·5	14·3
	4 „	17·6	19·2	19·2	18·6	17·1	16·1	14·0	12·3	16·2	17·0	17·9	16·8
	5 „	21·2	17·3	26·7	31·0	31·2	27·4	28·8	32·6	37·0	39·8	41·3	42·6
	6 „	39·2	38·8	39·9	39·8	40·3	40·8	34·0	39·2	38·4	40·8	30·6	32·3
	7 „	32·6	32·3	30·2	32·0	29·5	28·0	26·6	23·8	20·3	22·1	18·7	20·0
	8 „	17·1	18·2	15·0	16·1	17·9	18·1	20·9	21·5	22·1	21·8	22·7	23·5
	9 „	23·3	23·3	24·1	24·5	26·0	28·1	28·8	28·9	29·2	30·3	30·9	31·9
	10 „	31·9	30·8	28·7	27·2	29·2	28·7	26·4	27·5	28·3	31·8	31·5	29·8
	11 „	30·7	22·6	29·4	...	...	31·0	30·1	35·6	29·3	34·8	32·7	29·3
26	12 „	26·9	27·3	29·1	29·3	29·3	35·9	31·0	31·2	35·9	36·5	37·7	41·6
	1 A.M.	45·9	49·5	51·1	49·2	51·0	52·0	48·9	32·8	36·0	37·1	40·5	46·3
	2 „	52·1	55·9	47·1	39·8	40·8	47·7	51·7	50·8	49·4	48·6	46·2	45·1
	3 „	45·4	46·5	45·2	45·6	45·7	45·1	49·2	58·1	38·5	35·9	52·3	31·0
	4 „	11·4	0·00	4·0	9·6	13·7	49·4	62·8	46·8	45·4	29·4	34·8	53·5
	5 „	62·3	56·0	55·5	53·7	50·8	49·5	44·9	43·4	43·8	46·0	47·7	47·9

Increasing numbers denote an increase of easterly declination; the lowest reading (at $4^h\ 5^m$ A.M. 26th) has been taken as the zero.

OBSERVATORY AT TORONTO, CANADA.

Abstract of Observations taken during a remarkable disturbance on the 25th and 26th September, 1841.

Horizontal-Force Magnetometer.

	Gött. Mean Time.	m s 2 0	m s 7 0	m s 12 0	m s 17 0	m s 22 0	m s 27 0	m s 32 0	m s 37 0	m s 42 0	m s 47 0	m s 52 0	m s 57 0	H.F. Ther
25	10 A.M.	·00972	......	......	......	·00906	·00953	·00869	·00777	·00780	·00739	·00661	·00805	66·
	11 „	·00812	·00917	·00850	·00827	·00896	·01050	·00923	·00812	·00789	·00506	·00020	·00286	66·
	12 „	·00345	·00266	0·00	·00138	·00170	·00440	·00510	·00456	·00607	·00668	·00570	·00528	66·
	1 P.M.	·00558	·00547	·00428	·00332	·00355	·00547	·00609	·00671	·00833	·00759	·00461	·00320	66·
	2 „	·00301	·00409	·00642	·00629	·00493	·00364	·00862	·00397	·00471	·00461	·00514	·00579	65·8
	3 „	·00447	·00367	·00336	·00276	·00219	·00347	·00875	·00358	·00823	·00346	·00223	·00350	65·4
	4 „	·00371	·00438	·00565	·00400	·00428	·00400	·00482	·00604	·00609	·00811	·00738	·00885	65·6
	5 „	·00871	·00951	·01026	·01074	·00913	·00975	·01048	·01117	·01142	·01185	·01210	·01216	65·8
	6 „	·01295	·01352	·01325	·01173	·01126	·01071	·01202	·01394	·01480	·01419	·01282	·01362	66·0
	7 „	·01402	·01449	·01412	·01474	·01494	·01497	·01531	·01434	·01428	·01689	·01611	·01598	66·2
	8 „	·01419	·01618	·01588	·01537	·01571	·01591	·01475	·01464	·01475	·01452	·01496	·01553	66·3
	9 „	·01517	·01424	·01449	·01453	·01385	·01428	·01479	·01491	·01479	·01458	·01410	·01384	67·5
	10 „	·01392	·01441	·01474	·01598	·01640	·01676	·01733	·01790	·01702	·01797	·01728	·01740	67·4
	11 „	·02014	·02058	·01856	......	......	·01767	·01709	·01660	·01659	·01870	·01914	·01936	68·1
26	12 „	·02001	·02218	·02437	·02372	·02131	·02154	·02316	·02099	·01973	·01859	·01833	·01797	67·3
	1 A.M.	·01640	·01672	·01667	·01735	·01618	·01686	·01825	·01752	·01807	·02337	·01948	·01654	67·0
	2 „	......	·01119	·01074	·01191	·01292	·01263	·01117	·01191	·01423	·01374	·01236	·01221	66·8
	3 „	·01064	·00940	·00848	·00966	·01058	·01060	·01114	·00985	·00920	·01078	·01110	·00992	66·5
	4 „	·00885	·00981	·00680	·00643	·00850	·01067	·01825	·01173	·01372	·01144	·00804	·00799	66·
	5 „	......	·01197	·01316	·01292	·01342	·01347	·01346	·01279	·01243	·01247	·01328	·01366	66·

Changes of Total Intensity.

26	12 P.M.	·01236	·01237	·01361	·01257	·01185	·01181	·01213	·01169	·01144	·01149	·01151	·01119
	1 A.M.	·01113	·01083	·01082	·01052	·00953	·00960	·00903	·00953	·00933	·01026	·00961	·00786
	2 „	......	·00653	·00691	·00812	·00875	·00814	·00770	·00779	·00927	·00857	·00801	·00770
	3 „	·00709	·00633	·00646	·00669	·00724	·00698	·00647	·00516	·00606	·00508	·00191	·00206
	4 „	·00255	·00316	·00264	·00271	·00501	·00467	·00346	·00336	·00335	·00409	·00394	·00411
	5 „	......	·00505	·00552	·00569	·00606	·00597	·00614	·00607	·00630	·00633	·00652	......

The changes of horizontal and vertical force, and of the total intensity, are expressed in terms of the whole forces, and are uncorrected for variations of temperature, the precise corrections for which have not been yet determined, but the extreme corrections on this account would probably fall short of ·0003 in the horizontal, and ·0005 in the vertical force.

Increasing numbers denote an increase of force.

OBSERVATORY AT TORONTO, CANADA.

Abstract of Observations taken during a remarkable disturbance on the 25th and 26th September, 1841.

Vertical-Force Magnetometer.

	Gött. Mean Time.	m s 3 30	m s 8 30	m s 13 30	m s 18 30	m s 23 30	m s 28 30	m s 33 30	m s 38 30	m s 43 30	m s 48 30	m s 53 30	m s 58 30	V.F. Ther.
25	10 A.M.	·00234	……	……	……	·00178	·00191	·00177	·00177	·00184	·00173	·00146	·00267	66°·3
	11 „	·00330	·00277	·00263	·00263	·00286	·00291	·00260	·00216	·00216	·00103	·00142	·00182	67·5
	12 „	·00086	·00044	0·00	·00157	·00191	·00168	·00213	·00217	·00188	·00184	·00192	·00237	67·0
	1 P.M.	·00199	·00200	·00224	·00276	·00336	·00379	·00420	·00416	·00446	·00438	·00331	·00325	66·5
	2 „	·00394	·00418	·00434	·00431	·00487	·00484	·00465	·00498	·00537	·00514	·00571	·00559	65·8
	3 „	·00549	·00517	·00538	·00496	·00491	·00527	·00523	·00550	·00582	·00623	·00607	·00632	66·5
	4 „	·00637	·00666	·00693	·00692	·00712	·00691	·00719	·00752	·00776	·00769	·00755	·00769	65·7
	5 „	·00799	·00772	·00795	·00786	·00767	·00766	·00773	·00786	·00779	·00803	·00802	·00780	65·5
	6 „	·00821	·00823	·00812	·00806	·00819	·00821	·00850	·00851	·00857	·00846	·00846	·00875	65·7
	7 „	·00883	·00882	·00887	·00893	·00894	·00900	·00900	·00896	·00899	·00900	·00888	·00872	65·7
	8 „	·00862	·00857	·00857	·00842	·00835	·00826	·00799	·00791	·00780	·00768	·00754	·00763	66·0
	9 „	·00758	·00755	·00755	·00763	·00773	·00787	·00804	·00814	·00814	·00806	·00798	·00787	65·0
	10 „	·00792	·00805	·00850	·00897	·00905	·00914	·00943	·00963	·00969	·00973	·00977	·01004	66·0
	11 „	·01004	·01054	……	……	……	·01002	·01046	·00997	·01081	·01088	·01147	·01127	66·5
26	12 „	·01183	·01169	·01287	·01180	·01120	·01114	·01137	·01104	·01087	·01100	·01104	·01073	66·8
	1 A.M.	·01066	·01042	·01042	·01005	·00907	·00910	·00840	·00898	·00872	·00935	·00893	·00726	67·0
	2 „	·00622	·00621	·00664	·00786	·00846	·00783	·00746	·00750	·00893	·00821	·00771	·00739	67·0
	3 „	·00685	·00612	·00632	·00649	·00701	·00673	·00615	·00483	·00584	·00469	·00127	·00152	66·8
	4 „	·00211	·00270	·00235	·00245	·00477	·00425	·00278	·00278	·00263	·00358	·00366	·00384	67·5
	5 „	·00384	·00457	·00499	·00519	·00555	·00545	·00563	·00561	·00588	·00590	·00605	……	67·0

Changes of Inclination.

26	12 P.M.	6′·92	8′·87	9′·72	10′·08	8′·55	8′·79	9′·97	8′·41	7′·49	6′·42	6′·16	6′·12
	1 A.M.	4·85	5·33	5·28	6·17	6·01	6·56	8·33	7·22	7·91	11·85	8·92	7·85
	2 „	……	4·21	8·47	3·42	3·77	4·06	3·14	3·73	4·48	4·67	8·93	4·08
	3 „	3·20	2·77	1·83	2·68	3·02	3·27	4·22	4·24	2·84	5·15	8·81	7·10
	4 „	5·70	4·49	3·76	3·37	3·15	5·48	8·85	7·57	9·88	6·65	8·70	3·51
	5 „	……	6·26	6·91	6·54	6·65	6·11	5·56	5·54	6·07	6·62	6·78	……

Increasing numbers denote an increase of the vertical force, and a decrease of the inclination.

OBSERVATORY AT TORONTO, CANADA.

Abstract of Observations taken during a remarkable disturbance on the 25th and 26th September, 1841.

Gött. M. T.	Barometer Corrected.		Therm.		Wind.		Remarks.
Hour.	Height.	Th.	Dry.	Wet.	Direction.	Force.	
10 A.M.	29·289	66·0°	57·8°	56·2°	....	Calm	8·30 A.M. Rain slackened. Very densely clouded.
11 „	29·291	66·0	57·2	55·9	....	Calm	Densely clouded. Drizzling rain.
12 „	29·301	66·0	57·0	55·6	....	Calm	Densely clouded. Cirro-strati and haze.
1 P.M.	29·320	66·5	57·1	55·2	N.	Light	Densely clouded. Cirro-strati and haze.
2 „	29·331	66·0	57·4	55·6	North^y	Almost Calm	Densely clouded. Cirro-strati, dense haze, raining very slightly.
3 „	29·319	66·0	58·2	56·2	N.N.W.	Light	Densely clouded. Cirro-strati and dense haze.
4 „	29·319	66·0	59·6	56·4	N.	Nearly Calm	Densely clouded. Cir.-cum. and cir.-strati.
5 „	29·309	65·5	61·0	57·2	N.	Light	Clouded cirro-strati and cumulous haze.
6 „	29·309	66·0	61·5	57·1	N. by W.	Light	Densely clouded. Cir-cum. and cum.-strati.
7 „	29·313	66·0	62·7	57·9	N.W.	Mod^e	Densely clouded. Cir.-strati and cum.-strati.
8 „	29·323	66·0	62·0	56·5	N.W.	Mod^e	Densely clouded. Cir.-strati, a few breaks to the S. and S.W.
9 „	29·321	66·0	63·0	56·8	N.W.	Light	$\frac{5}{8}$ Clouded, cum.-strati and cir.-cum. Zenith clear.
10 „	29·308	67·0	65·0	56·8	N.W.	Light	$\frac{6}{8}$ Clouded. Light masses of cir.-cum.
11 „	29·306	67·0	65·6	56·4	N.W.	Light	$\frac{3}{8}$ Clouded. Light masses of cir.-cum., chiefly round horizon.
12 „	29·328	67·0	60·0	54·1	....	Calm	Fair. A few light cirri dispersed about.
1 A.M.	29·326	67·0	56·6	52·4	....	Calm	$\frac{1}{8}$ to the Sd. clouded with strati, remainder clear.
2 „	29·342	67·0	57·8	53·7	N.W.	Mod.	1h 10m. Faint auroral light to the northward. $\frac{7}{8}$ densely clouded.
3 „	29·332	66·5	57·2	53·7	N.W.	Light	$\frac{6}{8}$ overcast, cirri and cir.-strati. Zenith partially clear.
4 „	29·327	66·0	56·6	53·2	West^{ly}	Very light	Overcast. Strati and cir.-strati.
5 „	29·329	66·0	56·3	53·1	West^{ly}	Nearly calm	Densely clouded. Strati.
6 „	29·305	66·0	56·0	52·6	West^{ly}	Nearly calm	Densely clouded. Strati.

Additional Remarks.

Tor. M. T. 25th. **Gott. M. T. 26th.**

7^h 15^m P.M. 1^h 12^m A.M. Sky almost entirely clear. Bright bank of auroral light in the N., moving across the sky as light cirri.

7^h 20^m P.M. 1^h 17^m A.M. Several bright streamers and patches of light appearing and disappearing rapidly.

7^h 35^m P.M. 1^h 32^m A.M. Light brighter. Clouds rising rapidly.

7^h 38^m P.M. 1^h 35^m A.M. Sky overcast.

The sky continuing overcast, nothing further was seen of the aurora until 9^h 30^m P.M. (3^h 27^m A.M. Gött.), when the clouds being bright in the N.E. several splendid streamers, and bright pulsations were observed in that quarter; they remained visible until 9^h 55^m, becoming gradually more faint.

9^h 55^m P.M. 3^h 52^m A.M. Partially clouded round N. horizon, low bank of light in N. and N.E.

10^h 40^m P.M. 4^h 37^m A.M. Clearing slightly in N. Light larger and brighter.

11^h 40^m P.M. 5^h 37^m A.M. Densely clouded; nothing of aurora visible.

Midnight, 5^h 57^m A.M. Densely clouded; nothing of aurora visible.

Remarks relative to the Magnetic Disturbance at Toronto on the 25th and 26th of September, 1841.

The disturbances appear to have commenced at Toronto nearly at the same absolute time as at Greenwich, and to have been generally simultaneous at both stations. Additional observations were taken at Greenwich early in the morning of the 25th, the needles being in an agitated state, and an aurora being visible. Though additional observations were not commenced at Toronto at this time, the difference between the regular observations at 2 and 4 A.M., Gött. mean time, show a considerable disturbance; the change of declination between the hours of 2 and 4 amounting to $15'{\cdot}3$; the change of horizontal force to ·00444 of its whole value; and of vertical force to ·00202 of its whole value. The additional observations at Greenwich were soon after discontinued, the disturbance appearing to be over.

The readings at 10 A.M., Gött. mean time, exhibited so great a change at both stations, that extra observations were resumed at Greenwich, and commenced at Toronto.

The additional observations at Toronto were continued without intermission for 20 hours, from 10 A.M., Gött. mean time on the 25th, until 6 A.M., Gött. mean time on the 26th, each instrument being observed at intervals of 5 minutes, in the following order, viz.: Declin. $00^m\ 0^s$—H. F. $2^m\ 00^s$—V. F. $3^m\ 30^s$—Declin. $5^m\ 00^s$, &c.

The disturbance in the first hour (10 to 11) was not very great, compared with those that followed; but in the next 5 minutes, viz. from $11^h\ 00^m$ to $11^h\ 05^m$, the change of declination amounted to $19'{\cdot}6$; and between $11^h\ 27^m$ and $11^h\ 52^m$ the horizontal force had decreased by ·01030 of its whole value. These changes are specially noted, in consequence of there apparently having been no corresponding disturbance at Greenwich.

The disturbance at Toronto was at its height from 11 A.M. to 4 P.M., Gött. mean time: its general effect appears to have been that of causing a decrease of easterly variation and of *total* intensity.

The agreement in direction of the changes of horizontal and vertical force deserves remark: the minimum and maximum of each occurred simultaneously, or as nearly so as can be learned from the observations, the minimum of both being observed at the second reading after noon, and the maximum of both at precisely the same interval after the following midnight.

The observations at Toronto, being continued until midnight of Saturday at that station, which was 6 A.M., Gött. mean time of the 26th, lasted about five hours longer than those at Greenwich; and during these five hours a second disturbance was observed even greater than the preceding.

Between 4 and 10 P.M., Gött. mean time, the disturbance had been much lessened; it then increased rapidly, and the changes between 12 P.M. and 6 A.M. were very remarkable: in 15 minutes the declination magnetometer moved through an angle of $52'{\cdot}3$, and in 25 minutes more had returned through an angle of $62'{\cdot}8$ in the opposite direction. The horizontal and vertical-force magnetometers were also greatly disturbed, the change in the horizontal force amounting in 20 minutes to ·0122 of the whole force.

The changes of horizontal and vertical force in the last six hours have been reduced to the equivalent changes of inclination and total intensity, and are printed, for the convenience of comparison at these observatories, where the variations of the inclination and total intensity are directly observed. As the two magnetometers were not observed precisely simultaneously, the changes of inclination and total intensity can only be regarded as approximate, though the difference in the times of observation having been only 1½ minute, the errors occasioned thereby are probably seldom very great.

The observations of the second disturbance show a striking connexion between the changes of declination and intensity, an increase of force corresponding to an increase of easterly declination, and *vice versâ*: the same connexion was observed in the Toronto observations of the 29th of May, 1840.

Auroras.—An aurora was visible at Greenwich both in the morning and evening of the 25th. At Toronto the morning was heavily clouded, with rain, consequently no aurora could be seen: in the evening the aurora was visible at intervals from 7 to 10 P.M., Toronto time, or 1 to 5 A.M., Gött. time, the period of the second great disturbance; the remainder of the night was heavily clouded. A gale of wind occurred on the following day (26th), and in the evening another aurora was seen.

The *extreme* changes of the declination, horizontal, and vertical force, during the two disturbances, were as follows:—of the declination, 1° 05′; of the horizontal force, ·02438 of its whole value; and of the vertical force, ·01288 of its whole value. The days of occurrence, and the extreme ranges of the principal disturbances observed at Toronto in 1840 are subjoined, in order that the relative extent of the present disturbance may be estimated.

DATES.	EXTREME RANGES.		
1840.	Declination.	Horizontal Force.	Vertical Force.
	° ′		
May 29	1 59	Off scale, exceeding ·044	Off scale, exceeding ·024
August 28	1 44	0·03521	0·00846
September 22..	1 01	Not observed, being out of adjustment.	
„ 25..	0 30	0·00184	0·00112
December 21..	1 22	0·01522	0·01074
1841.			
Sept. 25 and 26	1 05	0·02438	0·01288

An aurora was observed on each of the above days in 1840; that of the 29th of May was the most brilliant of any seen since the establishment of the Observatory. Very few additional observations were taken either on the 22nd or 25th of September, 1840; on the last day especially, the few that were taken were not commenced until the greater part of the disturbance was apparently over; consequently the actual changes were, in all probability, much greater than those observed; the recurrence of so great a disturbance on the same day in the following year is remarkable. Additional observations have occasionally been taken in the course of every month in 1841, in consequence of unusual disturbances, but the changes have never equalled those above mentioned.

The months of September and October appear to be those of greatest disturbance.

Gauss's arrangement of the scale and mirror has been adopted for the horizontal-force magnetometer at Toronto, in consequence of the disturbance of the 29th of May, 1840, having driven the magnet beyond the range of the collimator scale. The range of the declination scale (on Professor Lloyd's plan) being about 6°,—or three times greater than the extreme range hitherto observed,—there is little probability of its ever being exceeded.

Postscript, Dec. 14th.—Whilst these pages were in the press, I received, through the kindness of Mr. Caldecott, the abstract of the observations made in September at the Magnetic Observatory instituted by the Rajah of Travancore, at Trevandrum, in lat. 8° 30′ 35·2″ N., and long. $5^h\ 7^m\ 59^s$ E.; by which I am enabled to state, that an unusual magnetic disturbance took place in India simultaneously with those observed in England and America; although, in consequence of the easterly position of Trevandrum, the commencement only of the disturbance was observed there. Each observatory discontinued its observations when its own Saturday night arrived; thus the observations at Greenwich continued five hours later than at Trevandrum, and at Toronto five hours later than at Greenwich; the latest observations, in each case, showing the continuance of the disturbance.

The observations at Trevandrum consist of the regular two-hourly readings of the three magnetometers, day and night. By comparing the positions of the magnetometers at each of the magnetic hours of the 25th of September, with the mean position at the same hour in the previous twenty-four days, we obtain what we may consider a measure of the magnetic disturbance of that day. As the disturbance was indicated principally by the horizontal-force magnetometer, we may commence with the comparison of that instrument, premising that as the inclination at Trevandrum is only — 2° 50′, the horizontal intensity at that station comprises nearly the whole magnetic intensity, the vertical component being extremely small.

Horizontal-Force Magnetometer, Trevandrum, September 25, 1841.

Mean Time.		Mean Position. 1st to 24th Sept.	Sept. 25.	Difference and Remarks.	
Trev.	Gött.				
h m	h	Scale Div.	Scale Div.		
0 28 A.M.	8 P.M.	120·3	131·4	11·1	Scale-divisions in excess on the 25th of September, corresponding to diminished intensity; one scale-division =·000133 nearly of the whole horizontal force at Trevandrum. The approximate *absolute* horizontal force, resulting from two experiments in the month of September, expressed in reference to the units of the British system, is 7·77. (Instructions of the Royal Society, p. 21.)
2 28	10	118·7	126·8	8·1	
4 28	Mid.	117·9	125·4	7·5	
6 28	2 A.M.	116·3	127·3	11·0	
8 28	4	111·0	124·2	13·2	
10 28	6	103·0	118·5	15·5	
0 28 P.M.	8	113·8	122·6	8·8	
2 28	10	125·1	140·2	15·1	
4 28	Noon.	128·0	160·1	32·1	
6 28	2 P.M.	124·7	167·1	42·4	
8 28	4	124·0	157·9	33·9	
10 28	6	122·3	171·6	49·3	

The positions in the Table are uncorrected for the variations of temperature of the bar, but the corrections on that account may be safely neglected for the present purpose: the thermometer of the horizontal-force magnetometer on the mean of the 12 magnetic hours of the 25th, was one degree of Fahrenheit *less* than the average of the month.

During the 24th of September the horizontal intensity differed little from its mean position, at the same hour, since the commencement of the month, until $10^h\ 28^m$ P.M., Trevandrum time, being the last observation of the day, when it was weaker than the average at that hour by an amount equal to about 7 scale-divisions. During the whole day of the 25th it was weaker than the average of the preceding twenty-four days of the month, by the quantities shown in the above table; and at the Göttingen hours of noon, 2, 4, and 6 P.M., when great disturbances were taking place at Greenwich and Toronto, the observations at Trevandrum show a decrease of intensity much exceeding the usual fluctuations. Mr. Caldecott has annexed the following remark to the readings at these hours:—"These irregular readings "examined into at the hours they were made, and found not to arise from "any instrumental irregularity.—J. C."

On the 26th, being Sunday, no observations were made; but the following table, exhibiting the *mean position* of the magnetometer *in each day* in September, shows that during the remaining days of the month the horizontal intensity did not return to its previous average value; corresponding with the remark deduced by Professor Kreil from ten perturbations observed at Prague, namely, that "the horizontal intensity remains weaker for some time after the "great oscillations have ceased, and only gradually resumes its ordinary "force[*]."

Mean Position of the Horizontal-Force Magnetometer in each day in September.

	Scale Div.		Scale Div.
1	123·8	18	124·0
2	118·3	20	123·7
3	113·5	21	124·6
4	114·1	22	123·5
6	110·9	23	119·8
7	110·4	24	117·4
8	116·9	25	139·4
9	114·5	27	133·0
10	117·0	28	129·9
11	117·3	29	129·5
13	122·7	30	130·0
14	127·5		
15	122·1	Mean position during the month	121·8
16	118·4		
17	125·1		

Declination Magnetometer.—The effect of the disturbance on the declination magnetometer at Trevandrum appears to have been comparatively small. The north end of the magnet was, however, during the whole day to the eastward of its average position at the same hours in the preceding part of the month, as is shown in the subjoined table. The second part of the table exemplifies the small amount of the fluctuations which take place from day to day in the mean position of this magnetometer at Trevandrum. The mean position *for the month*, corrected for torsion of the thread, was 253·48 scale-divisions, or the mean declination for the month = 0° 43′ 45·7″ East. A scale-division in this instrument = 39·85″nearly.

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[*] Letter to Lieut.-Col. Sabine, translated in Phil. Mag., Third Series, vol. xvii. p. 429.

Declination Magnetometer, Trevandrum, September 1841.

Mean Time.		Mean Position 1st to 24th Sept.	Sept. 25.	Diffs.	Mean Position in each day.			
Trev.	Gött.				Day.	Scale Div.	Day.	Scale Div.
h m	h	Scale Div.	Scale Div.					
0 28 A.M.	8 P.M.	253·5	254·2	0·7	1	253·4	16	253·3
2 28	10	253·6	255·3	1·7	2	253·6	17	252·7
4 28	Mid.	253·6	256·4	2·8	3	253·9	18	253·1
6 28	2 A.M.	255·4	257·1	1·7	4	253·1	20	253·9
8 28	4	254·3	256·0	1·7	6	253·3	21	253·0
10 28	6	251·9	253·6	1·7	7	253·3	22	253·3
0 28 P.M.	8	251·3	252·6	1·3	8	253·1	23	253·6
2 28	10	252·8	253·1	0·3	9	252·9	24	253·0
4 28	Noon.	253·3	253·4	0·1	10	253·3	25	254·7
6 28	2 P.M.	253·1	254·5	1·4	11	253·5	27	253·7
8 28	4	253·0	255·5	2·5	13	252·8	28	253·6
10 28	6	253·2	255·0	1·8	14	253·6	29	253·6
					15	253·6	30	253·6

Mr. Caldecott having arrived at Trevandrum in May 1841, and established his magnetic instruments in a temporary building until they were removed into the permanent observatory early in October, had not at that time determined the value of the readings of the Vertical-Force Magnetometer. For this reason a complete account of the disturbance of that component of the force cannot be given; and considering the very small amount of the whole vertical force at Trevandrum, it may perhaps be sufficient to state, that the readings of the instrument indicate an unusual difference in the force at the Göttingen hours of noon, 2, 4, and 6 P.M., from its value at the other magnetic hours of the same day.

SECOND POSTSCRIPT, Dec. 20th.—Whilst the Plate (I.) accompanying this notice was still in the engraver's hands, the arrival of the abstracts for the month of September from the magnetic observatory at St. Helena has furnished the means of adding to the present account the observations of this remarkable disturbance made at that station.

An unusual movement of the magnetometers appears to have been noticed by Lieut. Lefroy at an earlier period than at any observatory from which accounts have yet been received; extra observations having been commenced at St. Helena between 11 and 12 A.M., Gött. mean time, on Friday the 24th. At 2 P.M., the disturbance appearing to have subsided, they were discontinued, but were resumed at 8 P.M., and continued thenceforward without intermission for twenty-six hours, until midnight of Saturday the 25th. During these twenty-six hours of consecutive observation, the declination-magnetometer was observed at intervals of 5 minutes, and the horizontal and vertical-force instruments each at intervals of 10 minutes. The observations are given in the subjoined tables.

The element principally affected at St. Helena was the horizontal force, which underwent frequent fluctuations of unusual amount, and sustained, on the whole, a considerable diminution of intensity. Between 2 P.M. and 8 P.M. of the 24th, the loss of force amounted to about ·0048 of its whole value:

this weakened state remained, with little change, until 2 A.M. on the 25th, when the force again augmented, and had regained about half the original loss at 10 A.M., the period when the disturbances at Greenwich and Toronto occasioned extra observations to be commenced at those observatories. At this epoch another great diminution of the horizontal force took place at St. Helena, and the intensity continued to weaken until $7^h\ 42^m\ 30^s$ P.M., when the loss since 10 A.M. amounted to ·0118, and since noon of the preceding day, to ·015 of the whole force. The magnetic inclination at St. Helena being — 21°, the horizontal force forms by much the larger component of the total magnetic force: the approximate *absolute* horizontal value in English units may be taken at 5·9.

In the account of the Toronto observations it has been noticed that the greatest disturbance of the instruments took place after the observations at Greenwich had been discontinued; namely, after the midnight of Saturday at Greenwich. St. Helena being nearly in the same meridian as Greenwich, the observations ceased at nearly the same time and for the same reason: St. Helena does not therefore afford any observations corresponding to those of the second disturbance at Toronto.

On Sunday 26th, the instruments were observed at 9 and 11 A.M., 3 and 8 P.M.; and on Monday 27th, extra observations were commenced at $1^h\ 30^m$ A.M., at intervals of 30^m, and continued until 11 A.M., when the intervals were changed to 5^m for the declination-magnetometer, and to 10^m for each of the force-magnetometers, the extra observations being finally discontinued at midnight of that day.

A table is subjoined of the mean positions of the magnetometers at the several magnetic hours during the month of September, showing the mean diurnal curve for the month of each element; also a table of the mean positions of the instruments on each day of the month, showing the monthly curve. It is seen by the latter table that the horizontal force was considerably below its average intensity on the 25th, and that it did not wholly recover the loss before the end of the month.

The fluctuations of the declination at St. Helena, as at Trevandrum, were far less striking or remarkable than those of the horizontal intensity, or than those of the declination at Toronto and Greenwich. The magnetic disturbances at the tropical stations have not however always this character. During a disturbance observed at St. Helena on the 26th of June, 1840, the extreme range of the declination-magnetometer amounted to 1° 20′; and during several of the most extensive movements of the declination bar, Lieut. Lefroy states that the horizontal-force bar remained perfectly at rest. The following passages are extracted from Lieut. Lefroy's report of the disturbance here referred to (26th June, 1840), on account of their striking resemblance to some of the remarks in Mr. Airy's account of the recent disturbance at Greenwich:—

"On taking the reading for noon, my attention was called to the disturbed "state of the magnet; I found it making rapid and irregular movements, with "sudden jerks and momentary pauses, too rapid to allow readings......Two suc-"cessive movements frequently occurred in the *same direction*; and another "unusual circumstance was, that the magnet, after a violent movement, came "*instantly* to rest; it is for this reason that but two readings instead of three "are sometimes given."

With a view to a more complete examination of these singular phenomena, it is deserving of consideration, whether some slight modification might not be introduced in the mode of observing on such extraordinary occasions. For example, peculiarities of movement might be more advantageously studied and described by an observer, whose attention was not distracted by the necessity of recording the exact position of the bar at stated intervals of quick recurrence; and possibly a very light needle, read by a mirror, or by reflection from its own highly-polished side, and suited to follow more instantaneously than the declination bar the effects of rapidly-succeeding impulses, might be found useful in exhibiting the effect of each impulse more distinctly. An observer so circumstanced would note the time of those movements only which should appear to him deserving of special notice. Such observations might be made in addition to the readings of the magnetometers, which might continue to be made at intervals as short as the strength of each observatory will permit; and, where it can conveniently be done, the readings of the horizontal and vertical-force magnetometers should be simultaneous.

In a letter just received from Toronto, dated November 19, Lieut. Younghusband states, that though the curve of the 25th of September shows indeed extraordinary fluctuations, they are not to be compared to those observed on the night of the 18th November (1841), when the declination magnetometer ranged through above 86′, and the horizontal-force magnetometer went beyond the scale in Gauss's method of observation; a light held in the prolongation of the scale, about one foot from its extremity (equal to the length of about 200 divisions), was reflected from the mirror into the field of the telescope: whence the force must have been *diminished below the average more than* $\frac{1}{20}$*th of its whole value*: the greatest rapid change of force was equivalent to 0·03 of the total value, which was shown by a progressive movement of the magnet during five minutes. A very brilliant aurora accompanied this disturbance.

THIRD POSTSCRIPT, Dec. 29th.—Whilst finally revising the last page of this notice, the September returns from the magnetic observatory at the Cape of Good Hope have arrived. Although the reduction of these observations, for the purpose of subjoining them, would occasion an inexpedient delay in this publication, it is satisfactory to be able to state, that the remarkable disturbance under consideration manifested itself in that southern latitude; that it arrested the attention of Lieut. Eardley Wilmot at an early hour of the 24th; and that it was followed by that officer and his detachment with the utmost promptitude and assiduity. Extra observations, at the same intervals as on term days, were commenced at 6^h 12^m 30^s A.M. on the 24th, and continued to 10 A.M.; resumed at 2^h 35^m, and continued to 4 P.M.; resumed again at 6^h 5^m P.M., and continued without intermission for the succeeding thirty hours. The epochs here spoken of are Göttingen mean time. All the magnetometers were greatly affected. The greatest disturbance of the horizontal force commenced about 10 A.M. on the 25th, and attained its extreme limit at 7^h 45^m P.M. on the same day. The vertical-force magnetometer was deflected out of the field of view at 6^h 30^m P.M. on the 24th, and remained so: the instrument being adjusted afresh to the needle, the latter was again deflected out of the field at 2^h 27^m 30^s P.M. on the 25th.

The observations at the Cape may form a supplement to this notice, accompanied by observations of the same disturbance, expected to arrive by the next overland mail, from the magnetic observatory at Simla in the Himalaya, where, presuming it to have occurred, it is not likely to have escaped the indefatigable vigilance of Captain Boileau, of the Bengal Engineers, director of that observatory. The September returns from the Van Diemen's Land Observatory, conducted by Lieut. Kay, R.N., may be expected in February; about which time we may also hope to receive accounts of the same date from Captain Ross, R.N., who intended to pass the last fortnight of September at the Chatham Islands, where he would establish his magnetometers on shore.

OBSERVATORY AT ST. HELENA, September 24th and 25th, 1841.

Declination-Magnetometer.

	Gött. Mean Time.	m s 0 0	m s 5 0	m s 10 0	m s 15 0	m s 20 0	m s 25 0	m s 30 0	m s 35 0	m s 40 0	m s 45 0	m s 50 0	m s 55 0
24	11 A.M.	′ ...	′ ...	′ ...	′ ...	′ ...	′ ...	′ 8·39	′ ...	′ ...	′ 8·46	′ 8·53	′ 8·46
	12 „	8·46	8·53	8·53	8·96	9·10	9·17	9·24	9·24	9·74	9·74	9·81	9·81
	1 P.M.	9·81	9·81	9·74	9·39	9·32	9·53	9·46	9·24	9·17	9·24	9·10	9·10
	8 P.M.	3·63	3·70	3·70	3·77	3·77	3·56	3·48	3·48	3·34	3·41	3·56	3·48
	9 „	3·20	3·13	3·13	3·13	2·99	2·92	2·84	3·13	3·06	2·84	2·84	2·84
	10 „	2·84	2·84	2·84	2·84	2·84	2·78	2·84	2·84	2·84	3·13	3·06	2·64
	11 „	2·74	2·70	1·78	1·86	1·71	1·53	1·49	2·06	2·13	2·13	2·13	2·13
25	0 A.M.	2·56	2·91	3·03	2·91	2·84	2·75	2·70	2·56	2·06	1·92	1·92	1·99
	1 „	1·81	1·85	1·99	2·35	2·56	2·70	2·70	2·77	2·91	3·06	2·99	2·84
	2 „	2·78	2·84	2·84	2·99	3·20	2·64	2·82	3·13	3·34	3·41	3·41	3·41
	3 „	3·55	3·69	4·05	3·98	3·98	4·09	4·12	4·12	4·12	4·19	4·27	4·34
	4 „	4·34	4·90	5·19	5·26	...	5·69	5·69	5·76	5·97	6·18	6·33	6·47
	5 „	6·90	6·97	6·54	6·40	6·40	7·04	7·11	7·11	7·11	7·18	7·11	7·11
	6 „	7·18	7·11	7·04	7·04	7·11	7·39	7·39	7·53	7·61	7·75	7·75	7·82
	7 „	7·82	7·82	7·82	7·82	7·75	7·68	7·54	7·18	7·04	7·04	7·11	7·11
	8 „	7·11	7·04	6·86	6·79	6·65	6·61	6·55	6·55	6·54	6·66	6·86	6·97
	9 „	7·11	7·11	7·39	7·04	7·05	7·04	7·04	7·04	6·97	7·07	7·00	7·40
	10 „	6·90	6·90	6·43	6·71	6·97	6·83	6·40	6·12	5·76	5·76	5·76	5·69
	11 „	5·69	5·76	5·55	5·55	5·55	5·55	5·55	5·34	5·20	5·20	5·41	4·95
	12 „	4·62	4·23	4·41	4·41	4·27	4·27	4·77	4·84	4·48	4·13	3·49	3·60
	1 P.M.	3·77	3·39	3·34	3·41	3·48	3·55	3·41	3·41	3·85	3·99	3·94	4·27
	2 „	4·70	4·34	4·34	4·18	3·38	3·34	3·45	2·91	2·77	2·39	2·55	2·67
	3 „	2·84	2·84	2·84	2·77	2·42	2·67	3·36	4·03	4·55	3·82	4·12	3·55
	4 „	3·13	2·52	2·56	2·49	2·77	2·13	2·11	1·53	1·28	0·68	0·64	0·57
	5 „	0·37	0·30	0·01	0·07	0·0	0·53	0·57	0·58	0·64	1·21	1·33	1·41
	6 „	1·24	1·21	1·01	1·28	1·88	2·06	2·06	1·79	1·99	2·13	2·27	2·53
	7 „	2·84	2·91	3·05	3·05	3·05	3·33	3·19	3·40	2·91	3·05	2·91	3·46
	8 „	3·19	3·47	3·26	2·77	2·70	2·42	2·42	2·13	2·06	2·06	1·85	1·30
	9 „	1·42	1·42	1·42	1·42	2·06	2·06	2·10	2·70	2·77	2·91	3·05	2·41
	10 „	2·77	2·63	2·41	2·56	2·57	2·63	2·63	2·63	2·56	2·49	2·35	[illegible]
	11 „	2·27	2·34	2·20	2·13	2·13	1·92	1·64	1·50	1·50	1·42	1·42	[illegible]
	12 „	1·70	1·91	1·84	1·84	1·77	1·49	1·42	1·42	1·42	1·42	1·42	1·42

Increasing numbers denote a decrease of westerly declination.

Declination at 5h 20m P.M.; 23° 06′·42 W.

Gött. Mean Time.	Horizontal Force.						Vertical Force.					
	m s 2 30	m s 12 30	m s 22 30	m s 32 30	m s 42 30	m s 52 30	m s 7 30	m s 17 30	m s 27 30	m s 37 30	m s 47 30	m s 57 30
11 A.M.	...	...	...	171·6	...	172·0	...	...	...	...	7·2	6·3
Noon.	172·0	172·1	173·0	173·0	173·0	173·0	6·0	5·8	5·7	5·6	5·5	5·4
1 P.M.	173·0	172·8	172·85	172·6	172·1	171·1	5·1	5·0	4·7	4·9	4·6	4·0
8 P.M.	143·95	143·9	144·0	144·9	145·9	144·2	5·9	5·9	5·9	5·9	6·3	...
9 "	144·9	145·0	145·4	144·8	144·5	143·1	7·9	8·2	8·1	8·5	8·4	8·7
10 "	142·0	141·5	142·5	143·9	143·9	143·9	8·9	9·0	8·8	8·9	9·0	9·0
11 "	144·0	143·95	143·0	142·55	142·3	142·8	...	8·9	8·8	8·9	9·1	9·3
Midn.	144·57	144·9	144·9	145·35	145·9	146·2	9·8	9·9	9·9	9·9	9·8	9·8
1 A.M.	144·9	144·1	144·1	144·1	144·9	145·0	9·9	10·4	10·6	11·3	11·3	11·7
2 "	145·6	146·8	148·0	150·9	151·8	149·0	11·9	11·9	11·9	11·9	12·0	11·9
3 "	148·2	148·7	150·2	152·0	152·6	153·0	12·0	12·0	12·1	12·1	12·1	12·1
4 "	152·9	152·4	...	152·3	153·0	153·0	12·2	...	12·2	12·6	12·6	12·9
5 "	151·8	151·0	152·0	152·9	153·0	153·8	12·7	12·7	13·0	12·8	12·5	12·6
6 "	153·9	154·1	154·2	154·0	153·0	152·2	13·5	13·5	12·3	12·3	12·0	12·0
7 "	152·0	151·7	151·5	151·5	151·5	151·5	12·0	11·9	11·9	11·8	11·6	11·6
8 "	151·5	151·9	151·5	150·5	150·8	151·1	11·6	11·8	11·8	11·8	11·9	12·1
9 "	151·5	152·0	152·0	153·1	154·0	155·0	12·1	12·0	12·0	12·0	11·9	11·9
10 "	155·4	155·0	154·9	152·7	150·0	149·2	11·9	12·1	12·1	10·9	10·8	10·4
11 "	148·0	147·4	148·0	147·8	148·9	148·7	10·4	10·5	10·5	10·7	10·7	10·7
Noon.	144·2	142·9	140·95	140·05	140·5	138·05	10·7	10·6	10·6	10·5	10·5	10·2
1 P.M.	136·8	135·2	135·0	134·1	134·4	134·0	9·9	9·9	9·9	9·9	10·2	10·2
2 "	132·9	130·47	127·9	127·95	125·1	123·9	10·6	10·5	10·8	10·8	10·6	10·5
3 "	123·1	122·05	119·0	121·0	114·3	113·0	10·5	10·3	10·1	10·8	10·9	10·7
4 "	110·7	111·1	111·9	109·27	110·3	110·0	10·7	10·6	10·6	10·2	10·1	9·9
5 "	109·0	108·0	108·1	107·9	107·6	104·8	9·8	9·5	9·5	9·5	9·7	9·7
6 "	103·5	102·5	100·8	97·0	95·1	91·9	9·6	10·0	10·1	10·2	10·2	10·3
7 "	90·9	90·8	90·2	89·9	88·8	89·7	10·0	11·2	13·2	12·5	12·7	13·1
8 "	90·0	94·8	98·2	100·8	102·1	106·0	13·9	13·9	14·0	13·9	13·5	13·3
9 "	107·4	109·1	111·1	114·0	115·1	116·0	14·0	14·7	14·8	14·9	15·2	15·2
10 "	116·9	117·5	118·5	118·6	119·4	120·0	16·0	15·7	15·5	15·8	15·8	16·1
11 "	121·8	121·8	122·1	122·4	123·0	123·2	16·5	16·5	14·3	9·0	10·1	11·7
Midn.	123·2	123·3	123·3	123·1	123·0	123·0	14·3	14·5	15·3	15·5	16·2	16·5

The numbers are scale-divisions: coefficients for reduction into changes of force { Hor. Force 0·000177. Vert. Force 0·000225.

Observations taken on Sunday, 26th September, 1841.

Magnetometers.	Date.			
	9 A.M.	11.	3 P.M.	8.
Declination ……	4′·05	3′·63	4′·05	3′·63
Horizontal Force	Div. 148·2	Div. 151·6	Div. 148·2	Div. 143·8
Vertical Force …	16·0	…	16·0	13·2

Half-hourly observations of the Magnetometers from 1^h 30^m to 10^h 30^m A.M., 27th September.

Gött. Mean Time.	Declination.		Horizontal Force.		Vertical Force.	
Hour.	m s 00 00	m s 30 00	m s 2 30	m s 32 30	m s 57 30	m s 27 30
			Scale Div.	Scale Div.	Scale Div.	Scale Div.
1 A.M.	′ …	4′·48	…	149·2	…	14·4
2 "	4·46	4·48	147·9	147·5	14·1	14·1
3 "	4·12	4·05	147·0	147·2	14·0	13·8
4 "	3·77	…	147·9	…	13·8	…
5 "	…	…	…	…	…	…
6 "	3·84	4·12	149·6	149·6	14·5	14·5
7 "	4·87	4·91	149·0	148·3	14·6	14·4
8 "	3·48	3·13	150·0	148·5	14·2	14·5
9 "	1·96	1·14	146·0	144·6	14·1	13·6
10 "	1·71	1·78	147·0	148·1	13·2	11·6

Observations of Magnetometers continued, September 27.

Declination.														
Gött. Mean Time.	11 A.M.	12.	1 P.M.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1 A.M.
m s 0 00	1′·35	4′·12	6′·32	5′·69	5′·62	4′·84	2′·84	3′·48	4′·34	4′·83	4′·12	4′·41	4′·91	5′·33	5′·12
5 00	1·56	4·83	6·67	5·73	6·05	4·91	2·63	3·40	4·27	4·69	4·19	4·41	4·91	5·12	5·12
10 00	1·78	5·01	6·60	5·90	6·19	5·19	2·49	3·40	4·27	4·83	4·19	4·34	4·98	5·55	4·96
15 0	1·42	5·40	6·39	5·83	5·76	5·40	2·63	3·47	4·55	4·83	4·34	4·34	4·98	5·55	…
20 0	1·42	5·61	6·39	6·26	5·55	4·98	2·70	3·47	4·55	4·83	4·34	4·41	5·05	5·55	…
25 0	1·99	5·61	6·30	6·44	5·41	4·41	2·84	3·47	4·27	4·83	4·41	4·55	5·05	5·62	…
30 0	2·20	5·61	6·34	6·40	5·48	4·27	2·91	4·04	4·27	4·83	4·27	4·76	5·05	5·58	5·12
35 0	2·70	5·57	6·34	…	5·48	4·06	3·05	4·04	4·33	4·27	4·27	4·83	5·19	5·58	…
40 0	2·84	5·57	6·34	6·19	5·20	3·99	3·19	4·18	4·83	4·27	4·27	4·83	5·26	5·58	…
45 0	2·91	5·57	6·34	6·03	5·06	3·56	3·33	4·18	4·83	4·19	4·34	4·83	5·33	5·55	…
50 0	3·41	5·61	6·06	5·73	4·84	3·35	3·40	4·26	4·83	4·19	4·41	4·83	5·33	5·48	…
55 0	3·48	5·75	5·69	5·62	4·77	3·07	3·40	4·69	4·83	4·19	4·34	4·83	5·33	5·26	…

Observations of Magnetometers continued, September 27.

Horizontal Force.

Gött. Mean Time.	11 A.M.	12.	1 P.M.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	1 A.M.
	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.	Sc. Di.
2 30	145·1	152·0	149·0	145·8	146·1	145·0	139·4	141·1	139·0	144·0	140·0	142·0	144·1	147·1	149·2
12 30	145·1	152·0	147·27	144·0	146·0	142·3	140·0	141·2	139·7	144·0	140·1	142·0	144·8	149·0	...
22 30	146·0	151·0	145·75	144·77	145·8	142·6	141·0	141·1	140·9	143·0	140·7	142·5	145·1	150·0	...
32 30	148·0	149·8	144·7	145·0	145·1	141·1	140·9	141·1	142·0	142·0	141·2	142·9	145·5	150·0	149·9
42 30	149·2	149·0	144·6	145·9	143·8	140·8	140·6	140·0	142·8	140·1	142·0	143·0	146·0	149·9	...
52 30	150·9	148·6	144·9	146·0	142·0	140·2	140·9	139·0	143·0	139·1	142·4	143·8	146·2	149·2	...
Vertical Force.															
7 30	9·9	9·6	7·9	7·0	6·9	7·3	7·5	7·7	8·4	9·0	10·2	10·7	11·2	11·7	12·0
17 30	9·8	9·2	7·5	6·9	6·4	7·3	7·5	7·7	8·3	9·1	10·2	10·7	11·2	11·9	...
27 30	9·8	8·8	7·3	7·1	7·0	7·3	7·7	8·2	8·3	9·5	10·1	10·9	11·4	11·9	12·4
37 30	9·7	8·3	7·2	7·1	7·0	7·5	7·7	8·2	8·6	9·4	10·3	11·0	11·5	12·0	...
47 30	9·7	8·1	7·1	6·9	7·0	7·5	7·7	8·2	8·8	9·5	10·2	11·1	11·6	12·1	...
57 30	9·7	8·0	6·8	6·5	7·0	7·5	7·7	8·5	9·2	9·5	10·7	11·1	11·7	12·1	...

Half-hourly Observations from 2 A.M. to 9 A.M. of the 28th of September.

Gött. Mean Time.	Declination.		Horizontal Force.		Vertical Force.	
	m s 00 00	m s 30 00	m s 2 30	m s 32 30	m s 27 30	m s 57 30
	′	′	Scale Div.	Scale Div.	Scale Div.	Scale Div.
1 A.M.	......	......	......	......	......	12·7
2 „	5·40	4·98	150·0	150·6	13·1	13·4
3 „	4·91	4·91	150·0	150·0	13·7	13·8
4 „	4·91	......	150·0	......	......	......
5 „	......	......	......	......	......	13·7
6 „	4·46	5·09	151·2	151·9	13·8	13·8
7 „	6·27	5·69	150·9	150·0	13·9	14·0
8 „	4·83	4·76	151·2	151·9	14·2	14·4
9 „	4·27	......	153·0	......	......	......

Tables exhibiting the mean diurnal change of the Declination, Horizontal and Vertical Intensity, and the mean daily position of the several Instruments during the month of September 1841.

Gött. Mean Time.	Mean Values.		
	Declination.	Horizontal Intensity.	Vertical Intensity.
		Scale Div.	Scale Div.
0 A.M.	23° 01′·36	152·61	3·61
2 „	1·38	154·25	3·59
4 „	1·27	155·28	4·69
6 „	0·96	156·11	5·23
8 „	0·80	155·93	5·67
10 „	1·99	158·98	6·36
12 „	2·24	161·89	5·39
2 P.M.	1·58	159·65	4·32
4 „	2·07	153·91	3·43
6 „	2·02	151·11	2·55
8 „	1·46	150·02	3·07
10 „	1·48	150·98	3·49
12 „	1·36	152·61	3·61

Day.	Mean Values.	
	Declination.	Horiz. Intensity.
		Scale Divisions.
1	23° 2′·37	....
2	3·38	....
3	3·25	154·18
4	2·52	157·95
6	3·16	158·29
7	2·35	157·80
8	2·48	157·15
9	2·07	158·06
10	1·21	160·04
11	0·80	160·05
13	0·75	155·19
14	0·83	152·22
15	22 59·77	155·52
16	59·09	156·36
17	59·41	155·73
18	58·82	158·49
20	23 1·71	156·05
21	1·53	155·72
22	0·93	158·16
23	0·09	160·54
24	0·65	158·77
25	2·24	131·72
27	2·28	146·62
28	1·63	151·37
29	3·06	151·42
30	3·28	153·99

Dates and Extreme Ranges of the principal Magnetical Disturbances observed at St. Helena.

Date.	Declination.	Horizontal Intensity.	Vertical Intensity.	Remarks.
1840.				
June 26 and 27......	1° 25′·4	0·00127	....	Declination-Magnetometer observed at intervals of 5 minutes from 1 P.M. on the 26th to 9 A.M. on the 27th. Horizontal-force from 8 P.M. inclusive.
July 25	0 02·63	0·00339		
September 21 & 22	7·24	0·00579		
October 19	7·67	0·00500		
1841.				
March 22 and 23 ...	6·96	0·00598		
April 3	3·48	0·00554	0·00253	
September 25	9·80	0·01490	0·00281	

NOTICES

AND

ABSTRACTS OF COMMUNICATIONS

TO THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

AT THE

PLYMOUTH MEETING, AUGUST 1841.

ADVERTISEMENT.

The Editors of the following Notices consider themselves responsible only for the fidelity with which the views of the Authors are abstracted.

CONTENTS.

NOTICES AND ABSTRACTS OF MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

Page
Addendum to the Report of the Transactions of the Sections in 1839 1

MATHEMATICS AND PHYSICS.

Professor Sylvester on the relation of Sturm's Auxiliary Functions to the roots of an Algebraic Equation 23
Professor Powell on the Theoretical Computation of Refractive Indices 24
———————— on the Refraction of Heat.. 25
———————— on certain Points of the Wave-Theory of Light 25
Rev. Professor Lloyd's Results of some Investigations on the Phænomena of Thin Plates in Polarized Light 26
———————— on Simultaneous Changes of the Magnetic Elements at Different Stations 26
Rev. T. Dury on Sea Compasses 27
Mr. Thomas Hopkins on the Influence of Mountains on Temperature in the Winter in certain parts of the Northern Hemisphere 28
Mr. John Phillips on the Temperature of the Air in York Minster 29
Mr. John Phillips's further Researches on Rain at York, and at Harraby, near Carlisle, by Joseph Atkinson, Esq.; with Remarks by Prof. Phillips. 30
Mr. John Campbell Lees's Notice of a Meteorological Journal for the Year 1840, kept at Nassau, New Providence 32
Capt. Hewett's (the late) Letter to Capt. Beaufort, R.N. (referred to in a communication by Professor Whewell).. 32
Rev. Henry Moseley on a Machine for Calculating the Numerical Values of Definite Integrals 35
Mr. Fowler on a New Calculating Machine 39
Sir John F. W. Herschel's Letter on Photographic Engravings 40
Professor Elie Wartmann on Daltonism 40
Mr. E. J. Dent on the application of a Coating of Gold by the Electro-metallurgic process to the Steel Balance-springs of Chronometers 41
Professor Christie on the Preservation of Magnetic Needles and Bars from Oxidation by the Electrotype process 41

Page
Mr. J. **Bateman** on the Use of the Sliding Rule, with an account of some New Lines proposed for it 42
Mr. **Edmund Bowman** on Determining Distances by the Telescope........ 42
Mr. **De Moleyns** on recent Discoveries in Voltaic Combination 42
Mr. **Grellet** on an Instrument for Drawing Circles in Perspective........ 42
Mr. W. G. **Gutch**'s Notice of certain Barometers invented by Mr. Bursill 42

CHEMISTRY.

Mr. J. **Prideaux**'s Inquiries into the Causes of the increased Destructibility of Modern Copper Sheathing........ 43
Mr. R. **Hunt** on the influence of the Ferrocyanate of Potash on the Iodide of Silver, producing a highly sensitive Photographic Preparation 47
Professor **Daubeny** on Manures considered as Stimulants to Vegetation 47
———— on the Disintegration of the Dolomitic Rocks of the Tyrol 48
Dr. **Samuel L. Dana**'s Practical Method of determining the Quantity of Real Indigo in the Indigos of Commerce 49
Mr. **Goldsworthy Gurney**'s Experiments showing the possibility of Fire, from the Use of Hot Water in warming Buildings, and of Explosions in Steam-engine Boilers 49
Mr. A. **Booth** on Spontaneous Combustion 50
Mr. E. A. **Parnell** on some instances of Restrained Chemical Action........ 51
———— on some subjects connected with the Sulphocyanides...... 51
Mr. G. **Fownes** on the direct Formation of Cyanogen from its Elements 52
Dr. **Playfair**'s Abstract of a Letter from Professor Liebig 53
Mr. **Robert D. Thomson**'s new extemporaneous Process for the Production of Hydrocyanic Acid for Medical Use 54
———— on the Composition of Crystallized Diabetic Sugar 54
Professor **Bunsen** on the Radical of the Kakodyle Series 55
Mr. E. **Lankester** on the Production of Sulphuretted Hydrogen by the Action of Vegetable Matter on Solutions containing Sulphates 57
Mr. **Frederick De Moleyns**'s Inquiry into the Nature and Properties of the new Element, or product of Electrical Action mentioned by Schönbein 57

GEOLOGY AND PHYSICAL GEOGRAPHY.

Mr. J. E. **Bowman** on the Upper Silurian Rocks of Denbighshire........ 59
Mr. **Bartlett** on the Post-Tertiary Formations of Cornwall and Devon........ 61
Mr. C. W. **Peach**'s Account of the Fossil Organic Remains of the South-east Coast of Cornwall, and of Bodmin and Menheniott........ 61
Rev. D. **Williams** on the Stratified and Unstratified Volcanic Products in the neighbourhood of Plymouth 61
Mr. E. **Moore** on the discovery of Organic Remains, in a raised beach, in the Limestone Cliff under the Hoe at Plymouth.. 62

Page
Mr. E. Moore's Account of the Strata penetrated in sinking an Artesian Well at the Victoria Spa, Plymouth 63
Rev. Dr. Buckland's Notice of a series of Specimens from Mr. Johnson's Granite Quarries, near Prince Town, Dartmoor 64
Mr. Boswarra's Notice of the Heave of a Copper Lode 64
Mr. John Phillips on the Occurrence of some minute Fossil Crustaceans in Palæozoic Rocks 64
Mr. H. E. Strickland on the genus *Cardinia*, Agassiz, as characteristic of the Lias Formation 65
Mr. W. Walker on the Geological Changes produced by the *Saxicava rugosa* in Plymouth Sound 66
Mr. William Sanders's Notice of Sections of the Railway between Bristol and Bath, a distance of twelve miles, prepared by direction of a Committee of the British Association 67
Mr. John Craig's Notice of Sections of the Railways between Glasgow and Greenock, and Greenock and Ayr, prepared by direction of a Committee of the British Association 67
Mr. T. B. Jordan's Letter 'On Copying Fossils by a Galvanic Deposit' 67
Rev. Dr. Buckland's Notice of Models for Illustration of the Succession and Dislocations of Strata, Mineral Veins, &c., constructed by T. Sopwith, F.G.S. 67

ZOOLOGY AND BOTANY.

Mr. Jonathan Couch on the Zoology of the County of Cornwall 68
Mr. J. C. Bellamy on the Distribution, &c. of the Mammals of Devonshire... 68
Mr. John Edward Gray on the Geographical Distribution of the Animals of New Holland 68
———————— on a New Glirine Animal from Mexico 70
Professor Owen's Account of a *Thylacinus*, the great Dog-headed Opossum, one of the rarest and largest of the Marsupiate family of Animals 70
Mr. J. Richardson's Notices and Drawings of three new Genera of Marine Fishes from Van Diemen's Land 71
Captain Widdrington on the Habits of the Eel, and on the Freshwater Fish of Austria 71
Mr. E. Forbes on two remarkable Marine Invertebrata inhabiting the Ægean Sea 72
Mr. E. Lankester on Deposits in Springs, Rivers, and Lakes, from the existence of Infusoria 72
Professor Henslow on *Cecidomyia Tritici* 72
Colonel Hamilton Smith on the Colossal *Sepiadæ* 73
M. Edm. de Selys Longchamps' Projet d'observations annuelles sur la Périodicité des Oiseaux 73
Mr. P. F. Bellamy's Description of two Peruvian Mummies, presented to the Devon and Cornwall Natural History Society by Captain Blanckley, of the Royal Navy 75

Page
Dr. Caldwell on the Varieties of the Human Race 75
Rev. W. S. Hore's Remarks on the Flora of Devon and Cornwall........ 75
Captain Widdrington on some Species of European Pines........ 76
Mr. Robert Ball's Notice of destruction of Plants by Animal Odour 76
Mr. R. Patterson on Natural History as a Branch of Education 77
Mr. Bartlett's Comparative View of Animal and Vegetable Physiology 77

MEDICAL SCIENCE.

Dr. A. T. Thomson's Observations on a Pustular disease hitherto undescribed by writers on Diseases of the Skin 77
Dr. Theophilus Thompson's Abstract of a paper on the value of Opium as a remedy in Rheumatism, and on the circumstances which should regulate its employment........ 78
Mr. John Butter's General Observations on the Pathology and Cure of Squinting........ 79
Mr. J. V. Solomon's Facts as yet unnoticed in the Treating of Squinting...... 80
Mr. P. Bennett Lucas's Observations on two new Fasciæ connected with the Muscles of the Human Eye 80
Mr. Rumball's Observations on Asthma........ 80
Dr. Fowler's Observations on a Case of Deafness, Dumbness, and Blindness, with Remarks on the Muscular Sense 81
Sir D. J. H. Dickson's Abstracts of an extraordinary case of Albuminous Ascites, with Hydatids; of five cases of Hepatic Abscess, and of two cases of Phthisis 81
Dr. Macgowan on Empyema 82
Mr. William Joseph Square's Case of Empyema 82
Dr. D. B. Reid on Ventilation of Ships 82

STATISTICS.

Mr. H. Woollcombe on the Statistics of Plymouth, Stonehouse, and Devonport 82
Mr. Samuel Derry's Statistical Report of Patients of the Plymouth Public Dispensary, during the years 1838, 1839, and 1840 83
Sir C. Lemon on the Agricultural Products of Cornwall 83
Abstract of a Report on the Condition of the Working Classes in Kingston-upon-Hull 85
On the Economic Statistics of Sheffield, by a Committee 87
On the Vital Statistics of Sheffield, prepared by a local Committee, and forwarded to the Section by Dr. Holland 88
Mr. W. Neild's Comparative Statement of the Income and Expenditure of certain Families of the Working Classes in Manchester and Dukinfield, during the years 1836 and 1841 90

Page

Mr. **Henry John Porter**'s Account of the Monts de Piété of Rome, Paris, and other cities on the Continent 91

———————— on the Loan Funds in Ireland 93

Mr. A. **Ryland** on the Income of Scientific and Literary Societies, and the Amount paid for Rates and Taxes in the year 1840........ 95

Mr. **James Heywood**'s Report on the State of Education in the Polytechnic School at Paris, prepared at the request of James Heywood, F.R.S., by an English resident at Paris 96

Mrs. **Davies Gilbert**'s Results of some Experiments on a System of small Allotments and Spade Husbandry 98

M. **Quetelet**'s Account of the Establishment of a Central Statistical Commission in Brussels, by the Belgian Government 98

MECHANICS.

Mr. Wm. **Stuart** on the Plymouth Breakwater........ 99

Captain **Taylor** on a Floating Breakwater........ 100

Mr. G. **Rennie** on the Propulsion of Vessels by the Trapezium Paddle-wheel and Screw 101

Mr. W. **Chatfield** on Truscott's Plan for Reefing Paddle-wheels 101

Mr. J. **Grantham** on a Plan of Disengaging and Reconnecting the Paddle-wheels of Steam-engines........ 102

On Captain Couch's Chock Channels 102

Mr. J. M. **Rendel** on a System of Trussing for the Roadways of Suspension Bridges 102

Mr. J. S. **Enys**'s Remarks on the Connexion which exists between Improvements in Pitwork and the Duty of Steam-engines in Cornwall 103

Mr. **Charles Thornton Coathupe** on an improved Sight for Rifles and other Fire-arms........ 104

Mr. W. **Johnson** on the Granite Quarries of Dartmoor, and their Railways and Machinery 105

Mr. J. N. **Hearder** on Arnott's Stove, and the Construction of Descending Flues, and their Application to the purposes of Ventilation 105

Mr. **John Taylor** on the Water Power at Wheal Friendship Mine 106

Sir **Isambard Brunel** on the present state of the Thames Tunnel........ 106

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

Addendum to the Report of the Transactions of the Sections in 1839.

At the Meeting of the British Association in Birmingham in August 1839, Mr. Nasmyth communicated three papers, one to the Geological Section, on the Structure of Fossil Teeth; a second to the Medical Section, on the Microscopic Structure of the Teeth; and a third to the Medical Section, on the Structure of the Epithelium.

Agreeably to the practice of the Association, the paper read to the Geological Section was delivered to the Secretaries of that Section, Dr. Lloyd and Mr. Strickland; and an abstract of its contents having been prepared by Dr. Lloyd, for insertion in that portion of the annual volume which contains notices of the proceedings of the Sections, the original memoir and the abstract were transmitted to the Assistant General Secretary (Mr. Phillips), by whom the memoir was returned to Mr. Nasmyth.

With respect to the two papers read before the Medical Section, the practice above mentioned was not followed: no abstract of the contents of these papers was furnished by or through the Secretaries of the Section to the Assistant General Secretary.

Notices of Mr. Nasmyth's papers appeared in the Athenæum and Literary Gazette of the period: those journals usually obtain such notices either from authors themselves or from reporters of their own: in the present case the Council have been informed by the respective editors, that the report in the Athenæum of the two papers read to the Medical Section was supplied, and the proofs corrected, by Mr. Nasmyth himself, and the notice of the geological paper by the reporter of the Athenæum; and that the report in the Literary Gazette was drawn up by the reporter of that journal, from a rough manuscript furnished to him by Mr. Nasmyth.

In the October following the meeting, Mr. Nasmyth applied to Mr. Phillips to know whether the papers read by him at the meeting would be printed entire, or in the form of abstracts; and was acquainted in reply, that, according to usage, brief abstracts only could be inserted in the notices published by the Association, and unaccompanied by diagrams; the original memoirs and drawings being the author's own property, and at his own disposal.

On January 28, 1840, Mr. Nasmyth informed Mr. Phillips that he was preparing abstracts of his papers, and desired to know whether the papers read to the Geological and Medical Sections on nearly the same subject should be reported on as one, or kept separate. He also requested Mr. Phillips to obtain for him, from the Secretary of the Geological Section, the original memoir read at that Section, as an application which he had made for it himself remained unanswered, and he had only rough notes of that paper from which to make the abstract. Mr. Phillips informed him in reply, that one consecutive abstract of the three papers would be preferable, urging brevity and despatch; he at the same time returned the Geological memoir (as already stated) on or about the 10th of February.

On the 24th of February Mr. Nasmyth transmitted to Mr. Phillips an abstract, which he stated to contain the material points of the three papers, abbreviated as much as possible, and requested 200 private copies. Mr. Phillips has preserved no copy, and has no distinct recollection of his reply to this request, but thinks it probable he stated the custom of the Association in regard to private copies, and referred Mr. Nasmyth to the printer, Mr. R. Taylor, from whom he would have to receive them.

On the 2nd of April Mr. Nasmyth wrote to Mr. Phillips, expressing surprise at having that morning received in type "a small fragment of a separate report of one of his papers," after having been requested to give the substance of his three papers in one consecutive abstract, and having complied with that request. He was informed in reply, that it was by an error that any notice of Mr. Nasmyth's geological paper had been put amongst the papers of that section, beyond a mere reference; that it should be cancelled; and that it was intended to give the abstract furnished by Mr. Nasmyth in one continuous article in the proceedings of the Medical Section; but as the manuscript appeared very long, Mr. Phillips suggested some omissions, which being assented to by Mr. Nasmyth in a letter of the 10th April, the manuscript was sent to the printing-office. The proofs, of which the printer states there were several, passed directly between Mr. Nasmyth and the printing-office, the manuscript and all the proofs, except the last corrected revise, being retained by Mr. Nasmyth. All the other sheets of the volume passed through Mr. Phillips's hands in their progress through the press, as is the usual practice: the exception in this case appears to have been occasioned by Mr. Phillips's temporary absence from York, and the printer's desire to hasten the volume through the press.

When the proofs were finally corrected, Mr. Nasmyth applied to the printer for 100 private copies, and was informed that, without an order, his request could not be complied with until the volume was published. Mr. Nasmyth then enclosed, or brought to the printing-office, a note from Mr. Phillips to himself, the exact purport of which Mr. Taylor cannot now recall, but which appeared to him at the time to authorize a compliance with Mr. Nasmyth's request: the copies were accordingly delivered.

On June 10 Professor Owen wrote to Mr. Phillips, calling his attention to the following sentence in the Medical Gazette of the 5th of June:—"In "Mr. Nasmyth's own report given in the Transactions of the British Asso- "ciation, which has been printed separately, and of which a copy is now "before us, we find it stated that the ivory is neither more nor less than the "ossified pulp, and that it can in no wise be regarded as an unorganized "body." Mr. Owen denied, on the authority of the contemporaneous reports in the Athenæum and Literary Gazette, that Mr. Nasmyth's papers read at Birmingham would justify an abstract containing the statement thus printed in the Medical Gazette, and claimed the theory of the development of teeth, ascribed therein to Mr. Nasmyth, as his own, communicated to the French Institute and published in the 'Comptes Rendus' in the December following the meeting at Birmingham. Mr. Owen concluded by requesting Mr. Phillips to suspend the publication, in the volume of the Association's Reports, of the abstract containing the statement in the Medical Gazette, until its fidelity should be shown by comparison with the original documents.

Mr. Phillips expressed, in reply, his surprise at the information received from Mr. Owen, inasmuch as not having seen any proofs, he was not aware that Mr. Nasmyth's abstract had passed through the press, and as he had certainly not meant to have sanctioned the delivery of any private copies before the publication of the volume; that Mr. Nasmyth, however, could not be regarded as at all responsible for these irregularities; that full confidence had always been placed in the communications from authors, and that no such question had ever occurred before; and that unless Mr. Owen should take the formal step of an appeal to the Council, in which case it would become his (Mr. Phillips's) duty to await the directions he should receive from that body, he could neither suppress nor suspend the publication.

On the 24th of June Mr. Phillips addressed the following letter to Mr. Nasmyth:—

"York, June 24, 1840.

"Sir,

"I have this moment received from Mr. R. Taylor, for the first time, a proof of the abstract of your memoirs on Odontology, and am concerned to find that you have made *additions** to it since I forwarded the MS. to be set up. This is grievous; but what astonishes me more, is to learn that, without my knowledge, you have received copies of the paper in this unauthentic state, and communicated extracts, or the whole, to a Medical Review.

"These unfortunate circumstances place me in a painful position; but their effect is more to be regretted on your account, since they deprive me altogether of the power of substantiating the authenticity of your communications.

"Yours very truly,

"JOHN PHILLIPS."

"*Alexander Nasmyth, Esq.*"

To this letter Mr. Nasmyth replied as follows:—

"*To Professor Phillips.*

"13 A, George Street, Hanover Square,
June 27, 1840.

"Sir,

"It is with feelings of no little astonishment that I perused your letter of June 24th, received yesterday; and I am quite at a loss to divine in what way I have deviated with respect to the publication of my abstract in the Transactions from the ordinary course of proceeding. More than six weeks ago, a proof of my paper was transmitted to me, and I was never more surprised than on learning that you did not receive one before June 24th. I corrected my proof, and received a revise of it, which I duly returned; and of course had every right to presume that either the proof or revise was submitted to the Editor of the publication to which I was contributing. With respect to the corrections made, I at once undertake to prove that they consisted in *no interpolation whatever of new matter*, but merely in alterations, rendering the abstract a more faithful digest of my papers *as reported in the Literary Gazette and Athenæum*, and am therefore still more unable to understand the propriety of this interference with my clear right to do justice to my papers in their authentic report. As to the printing separate copies of my abstract, as I have had several letters from you, authorising me to give publicity to it in any way I choose, I cannot suppose I was doing wrong in making use of a permission freely granted.

"I remain, Sir, your obedient servant,

"A. J. NASMYTH."

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* The words in Italics in this and the subsequent letters, and in the reports to the Council, were underlined in the originals.

On the 18th of July, Mr. Owen addressed the following appeal to the Council, to Mr. Yates, Secretary of the Council; and informed Mr. Phillips that he had taken this step:—

"My dear Sir, "Royal College of Surgeons, July 18, 1840.

"You may feel assured that it is with very great regret that I trespass on your valuable time in respect of a personal matter: if it had been, however, merely personal, I should have refrained; but the case is one that might be quoted to the detriment of the character of the Scientific Transactions of the British Association, with regard to the laxity with which authors, communicating their views at the meeting, are afterwards allowed to represent themselves as having so communicated their views, when the volume comes, some months afterwards, to be published. My request is, that the publication of Mr. Nasmyth's paper in the forthcoming volume be suppressed, or the original paper, as read at Birmingham in August last, be substituted, on the ground that it has been altered by the author, both in the way of substitution of new matter, and omission of old, in order to include a discovery of mine, published December 16, 1839, and likewise, because the author has made use of the proof of his memoir, as so altered, to found a charge of plagiarism against me, which has been published, anonymously, in the Medical Journals, Lancet, and Medical Gazette.

"In proof of these allegations, I transmit the following:—

"1. Literary Gazette, containing a verbatim* report of Mr. Nasmyth's Memoir, as read at Birmingham, August 12, 1839.

"2. '*Comptes Rendus*,' containing the abstract of my Memoir, published December 16, 1840.†.

"3. Proof of Mr. Nasmyth's modified memoir, now standing in type for the forthcoming memoir.

"4 and 5. Simultaneous attacks on me in the Lancet and Gazette, founded chiefly on a comparison of the privately circulated proof, with my published memoir; such proof being made to represent the Transactions of the British Association, Vol. VIII. (!)

"6. My answer.

"The question at issue is, whether Mr. Nasmyth described at Birmingham the cellular ivory of the tooth as being the ossified pulp.

"I have marked with a marginal line the paragraphs in the Literary Gazette, and the modified proof which relate to dental development.

"Prof. Phillips has probably communicated with you on the subject. As injustice will be done to me if the Association sanction the publication of Mr. Nasmyth's views in the corrected proof, as exponents of what he enunciated in August last, it seems to be a not unreasonable request that the publication of at least that portion of his paper in question be postponed till its real correspondence with his memoir of August last be ascertained.

"He (Mr. N.) has obtained *Private Copies* of his modified memoir, and has anticipated the publication of the Society's volume, by transmitting them to the Institute at Paris and other Societies, as well as to the editors of journals, for comparison with my memoir of December.

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* On a reference made by Mr. Yates to the Reporter of the Literary Gazette, the following statement was given by that gentleman in explanation of the use of the word "verbatim."

"The Report on the Memoir on Epithelium is a 'verbatim' copy of the rough manuscript "supplied by Mr. Nasmyth. The Report on the Physiology of Teeth is fully and accurately "given in accordance with the manuscript [supplied by Mr. Nasmyth], with the exception of "those portions referring to diagrams, which would perhaps have more clearly explained the "author's views, but which, without the drawings themselves, I considered could not have "assisted the reader, and with the further exception of any errors of judgement exercised by "me, such as the above consideration may evidence." The paragraphs marked by Mr. Owen with a marginal line were in the Report on the Physiology of Teeth.

† Mr. Owen's communication to the Institute was read on the 16th December, and published in the 'Comptes Rendus' on the 23rd of December.

"Believe me, my dear Sir, faithfully yours,

"*James Yates, Esq., &c. &c.,* "RICHARD OWEN."
"*Sec. Council, British Association.*"

Mr. Yates was unfortunately absent from England when Mr. Owen's letter reached his house. Both the General Secretaries were also on the Continent, and most of the other members of the Council were absent from London, so that it was found impossible to assemble a Council to receive and consider Mr. Owen's appeal before the assembly of the members at Glasgow, at the meeting of the Association in September.

On the 10th of August Mr. Phillips informed Mr. Nasmyth in the following letter of the course he felt it his duty to follow under these novel and very embarrassing circumstances:—

"SIR, "York, August 10, 1840.

"The course of proceeding which I have thought it my duty to adopt, in regard to the publication of your paper, is this:—The printer will lose no time in finishing the volume, the abstract of your papers omitted; he will also retain in type the whole of your abstract, in the form you have given it, in order that, should the Council direct it to be introduced, it may, with as little delay as possible, be added to the volume, whether published or not, and the opinion of the Council on the case, so far as by copies of all the letters I have received, and by reference to public documents, it can be justly stated to them, will be requested on the very earliest possible occasion; this being what I conceive the line of my duty, in consequence of the appeal which Professor Owen has made to the Council (Mr. Yates and the General Secretaries being unfortunately absent). I shall be both surprised and grieved if you interpret as intended injustice to yourself what certainly is based on a conscientious desire to conduct myself rightly in circumstances such as happily have not occurred before in connexion with the British Association.

"That you should be dissatisfied with the suspension of the printing of your paper, is an almost necessary consequence; but I really cannot suppose that your displeasure at this proceeding on my part will prevent you from furnishing to the Council, through their Secretary, Mr. Yates, such of the original documents which you mention as may be sufficient to prove the accuracy of the abstract you desire to have printed. Should you, however, instead of this easy and obvious method of correcting any error of mine, resolve to appeal to another tribunal, the public, I will give you the only proof in my power to offer of an unbiassed mind, by transmitting copies of all the letters I have received from you, to render any statement you may think proper to make as complete as possible. "I am, &c. &c.

"*A. Nasmyth, Esq.*" "JOHN PHILLIPS."

To this Mr. Nasmyth replied as follows:—

"13 A, George Street, Hanover Square,
12th August, 1840.

"*To Professor John Phillips.*

"SIR,

"I have to acknowledge the receipt of yours of the 10th instant, and in reply have to state, that notwithstanding I have already fully done my duty to the British Association, it must be perfectly clear to you that I can have no possible objection to submit the documents required to you for your satisfaction. It must also be clear to you, as you of course know the circumstances, that I cannot consistently with what is due to myself place any papers, drawings, or other documents containing unpublished matter, in the way of falling under Mr. Owen's inspection, having suffered so much already in that quarter. Since I have had the papers in my possession I have continued my investigations, and the blank pages of the original papers contain much recent original matter. The books of drawings and separate sheets of drawings themselves contain the requisite illustrations of these recent researches; I could not, therefore, on that account, submit them where they would run the least risk of inspection by that gentleman; and even were there no original matter, I cannot, under the circumstances which have occurred, submit myself to any tribunal over which he has the least shadow of control. However, I in no way wish to elicit an opinion from you on these points, but I beg to say that as you are the person who ought, as editor of the Transactions of the British Association, to be satisfied of the correctness of any abstract or epitome published by you in that capacity, I will, if you choose, either show you here, or without hesitation I will even take the trouble of conveying to you at York the whole of my preparations, drawings and original manuscripts, which I had with me at Birmingham, under the express condition, however, that Mr. Owen is not allowed to see them, or in any way whatever to interfere. I must remind you, however, that all these have already been in your power, and the MSS. in your possession for some time, and that every opportunity has been rendered by me already for any one of the Council to satisfy himself on any point: the circumstances which have since occurred, and those which I have above alluded to, form sufficient grounds for not submitting any documents to the Council again* as a body, though for your satisfaction, as Editorial Secretary, I can have no hesitation in submitting them. In stating this I beg it to be distinctly understood that I mean no disrespect to the body collectively, or to its members individually.

"I only wait therefore your answer, in the hope that as you alone are now responsible for what is published, your eye alone need be satisfied, a satisfaction which was equally in your power and that of the Council for some time already, and which time was only limited by their own choice, and not by any importunity on my part to have the papers back.

"I need not observe that a great difficulty connected with the step of forwarding my original documents is the size of the illustrations, drawings, &c.; the necessity of these to elucidate the original papers (the whole being a piece of descriptive microscopic anatomy,) you may judge of by the desire I evinced to you of having some of these illustrations introduced in the abstract. That, however, shall not stand in the way of satisfying you, and prevent the necessity of a step which I should deplore as much as any one. I can assure you, Sir, that it was with the utmost reluctance I took any step at all with reference to Prof. Owen's treatment of me, but I am happy in feeling that every member of the profession with whom I am acquainted, and many besides, think that I have only done what was due to myself; and I am quite sure that any one who knows me will give me credit for a love of anything rather than disputes, especially public disputations, as my forbearance for so long a period may testify. I have laboured hard for some years in a particular line of discovery, and you would feel as strongly as any one that it is not pleasant to have the results of your own labours appropriated by another, and then the accidental position of that other on a Council of a Society where your own discoveries were first made public (upon whose protection you throw yourself) acting as a check upon the publication of an ungarbled epitome of what you had really said.

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* There is some mistake here; no documents of Mr. Nasmyth's, nor any question having any relation to them, had ever been before the Council at the time that this letter was written.

"Such is my case, and I leave it in your hands. I am very happy to know that it is by Prof. Owen's instigations that this act of justice is denied me. But I hope by the course I have proposed in this letter to induce you, as the organ of the Association, not to commit an act of injustice which one interested member of its Council would induce it to commit.

"I shall be ready either to go to York to communicate with you, or to see you here. I need not inform you of the very great inconvenience it will be to me to leave town even for a day at present, and it would be of much consequence to me if it could be spared.

"I remain, Sir, your very obedient servant,
"ALEXANDER NASMYTH."

It may be proper here to remark, that when Mr. Nasmyth wrote this letter, Mr. Owen was himself a member of the Council: he ceased to be so in the new Council appointed at Glasgow*; and he was not present at the only meeting of the former Council, in which the question of Mr. Nasmyth's paper came under consideration, namely, in September.

Mr. Nasmyth's offer to convey his original memoir to York, for Mr. Phillips's satisfaction, was declined, as, an appeal having been made to the Council, the case was removed out of his jurisdiction.

On the 5th of September Mr. Nasmyth enclosed to Mr. Yates the following letter, to be laid before the Council at the same time with Mr. Owen's appeal:—

"*To the Council of the British Association.*

"13 A, George Street, Hanover Square,
5th Sept., 1840.

"GENTLEMEN,

"Professor Phillips, the Assistant Secretary to the British Association, having, on a simple application from Mr. Owen, without any authority or investigation on the subject, although I repeatedly offered him all the means and facilities in my power, and even offered to take all the materials and papers connected with my communications to York for his individual satisfaction, at once suppressed, in the volume of the Transactions of the past year, the whole of a report of three contributions made by me on three different subjects to the last meeting of the British Association; though one of these had not the slightest connexion with the point in which Mr. Owen's application originated; though all of them had been approved by the Council†, read and demonstrated at the public meetings of its Sections, and the original papers themselves had remained in the hands of its officers, and been 'reported' under the direction of Professor Phillips; and though the abstract, made out at his request, had been, after his inspection, condensed and shortened at his especial suggestion, gladly inserted by him, corrected in proof under his superintendence, and printed, and communicated to me in a separate form with his authorization;—I now respectfully demand from you the restoration of my abstract to its proper place in all the copies of the Transactions hereafter circulated, and that an apology for its omission be instantly circulated and sent to the possessors of the volumes hitherto sold. If Professor Phillips has any cause of complaint against me, I shall instantly be ready to defend myself, if common fairnesss is first shown me, and my privileges restored; but I protest against his having first, without even the

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[*] Having been on the Councils of 1838 and 1839.

[†] Mr. Nasmyth was in error in supposing that either his original memoirs or his abstract had ever been seen by the Council.

distinct allegation of a relevant deviation from propriety on my part, and certainly without an attempt on his part to try the validity of any justification, taken extreme measures against me, and then, in fact, arbitrarily passed and executed sentence upon me before trial, or even a relevant or distinct charge. Such a line of conduct in my opinion savours of persecution, and is certainly at direct variance with British ideas of justice, and I am confident that the British Association for the Advancement and Encouragement of Science will never sanction for an instant such a total subversion of the fundamental bond of union of the Association.

"I am, Gentlemen, your obedient servant,
(Signed) "ALEXANDER NASMYTH."

In September the volume of the Transactions was published, containing in its sectional notices, the title of Mr. Nasmyth's papers read at the Birmingham Meeting, but, as in the case of many other papers in that volume, and in others, without any abstract being given of their contents.

On the 15th of September, being the earliest day on which the Council could be assembled, they met at Glasgow, having before them the letters above noticed, and a statement from Mr. Phillips that he had never seen either of the two papers read by Mr. Nasmyth to the Medical Section. Whereupon the following Resolutions were adopted:—

1. That the Council approve of the decision of Mr. Phillips to suspend the publication of Mr. Nasmyth's paper, pending an appeal to the Council from Professor Owen, relative to the correctness of Mr. Nasmyth's report of that paper.
2. That it be referred to the President and other officers of the Medical Section at Birmingham, to decide whether the report of Mr. Nasmyth's paper, as published in the Literary Gazette and Athenæum, or in either of those periodicals, or the report of that paper sent by Mr. Nasmyth to Mr. Phillips for publication in the 'Report of the Ninth Meeting of the Association held at Birmingham,' is more correct in regard to the points under discussion between Professor Owen and Mr. Nasmyth, and that the President of the Medical Section be requested to communicate the result to the Council at his earliest convenience.
3. That these Resolutions be communicated to Professor Owen and Mr. Nasmyth.

On the 19th of November the Report of the Referees was received by the Council: it was as follows:—

Reference having been made to us by a Council of the British Association for our opinion whether the report of Mr. Nasmyth's paper, as published in the Literary Gazette and Athenæum, or in either of those two periodicals, or the report of that paper sent by Mr. Nasmyth to Mr. Phillips for publication in the Report of the Ninth Meeting of the Association, held at Birmingham, is more correct with regard to the points under discussion between Professor Owen and Mr. Nasmyth, we have carefully examined these several documents, and it appears to us that the main point under discussion between these two gentlemen is, whether the account of the process of dentition, contained in Mr. Nasmyth's paper, did or did not comprise the theory that the ivory of the teeth is formed by the ossification of the pulp. We find, with reference to this question, that in the accounts of Mr. Nasmyth's paper, given in the Literary Gazette and Athenæum, his opinions on that subject are involved in considerable ambiguity; for, while some passages in them would imply that he considered the proper substance of the teeth as being formed by the addition of ossific matter in the original structure of the pulp, commencing and proceeding on its surface, these reports contain, at the same time, other passages, in which the theory of the ossification of the pulp is distinctly and expressly disclaimed by Mr. Nasmyth; whereas in the abstract of his paper, drawn up by himself, with a view to publication in the Report of the Association, this theory is very explicitly and unequivocally maintained. Whether this theory was distinctly advanced in the original paper read to the Medical Section at Birmingham, it is not in our power to determine, because that paper is not before us, and because we have no other evidence of the nature of its contents than the printed documents already referred to.

(Signed) JAMES MACARTNEY,
One of the Vice-Presidents of the Medical Section at the Birmingham Meeting.

P. M. ROGET,
One of the Vice-Presidents of the Medical Section at the Birmingham Meeting.

G. O. REES,
One of the Secretaries of the Medical Section at the Meeting at Birmingham.

November 16th, 1840.

This Report having been considered, the Council resolved,—

1. That the Council do not consider it necessary to make any further publication of Mr. Nasmyth's communication than the notice inserted in the Report of the Ninth Meeting of the Association, held at Birmingham.
2. That this Resolution be communicated to Mr. Nasmyth and Professor Owen.
3. That the thanks of the Council be returned to the Authors of the above Report, for the care and attention which they have employed in preparing it, and that they be furnished with a copy of the preceding Resolutions.

On the 8th of January 1841, the Council received, through their Secretary Mr. Yates, a communication from Mr. Nasmyth, dated January 7th, still pressing the publication of his abstract in the volume of the Association Reports, and expressing his readiness and desire to lay before the Council the engravings from the drawings which had accompanied his papers read at Birmingham. There appeared from this communication reason to suppose that Mr. Nasmyth might no longer entertain the indisposition expressed in his letter to Mr. Phillips of the 12th of August, to allow the Council to have the original memoirs for the purpose of comparison with the abstract; and as by this comparison alone their agreement or disagreement with each other could be ascertained, and the Council be enabled (on the supposition of their agreement) to publish Mr. Nasmyth's abstract with their own authentication, the following Resolution was adopted:—

"That Mr. Yates be requested to obtain from Mr. Nasmyth the original memoir or memoirs read by him to the Medical Section at Birmingham, with a statement that no alterations have been made in them; and to refer them to the authors of the Report to the Council, dated November 16, 1840, for the purpose of enabling them to decide upon the correctness of the abstract presented by Mr. Nasmyth for publication in the Report of the Ninth Meeting of the Association held at Birmingham; and that the Referees be requested to report the result of their inquiries to the Council at their earliest convenience."

At a meeting of the Council on the 27th of February, the following letter was presented from Dr. Roget, addressed to Mr. Yates, Secretary of the Council:—

"Dear Sir, "Bernard Street, January 21, 1841.

"Dr. Rees and myself, having taken into our consideration the letter which you wrote to both of us the day before yesterday, beg, in answer, to refer you to the letter of Dr. Macartney, of the 12th instant, addressed to yourself (which we return inclosed), and to express our entire concurrence in the opinion he there gives on the subject of the new reference made to us by the Council of the British Association. The question at issue between Mr. Nasmyth and Mr. Owen being one of considerable delicacy, we have thought it right to protect ourselves from all suspicion of being biassed in our judgement by *ex parte* statements or representations; and we have accordingly scrupulously avoided having any communication with Mr. Owen, either directly or indirectly, on the matters in dispute. For the same reason we must decline the proffered interview with Mr. Nasmyth, and the more so as we feel that the question, on which the Council request our opinion, would become more involved and difficult of solution by the introduction of matters really foreign to it, which would unavoidably result from such an interview. The simple question, as it appears to us, turns upon the matter contained in the original memoirs, in the identical state in which they were read to the Sections of the Association at Birmingham. Mr. Nasmyth having subsequently made many additions and alterations in these manuscripts, and not having consented to restore them to their former state, as proposed by Dr. Macartney, and having declined to place in the hands of the Referees the original memoirs, as desired by the Council, we are consequently unable to execute the task they have requested us to undertake.

"Dear Sir, faithfully yours,

"*Rev. James Yates.*" (Signed) "P. M. Roget."

Dr. Macartney's proposal referred to by Dr. Roget, contained in his letter of the 12th of January to Mr. Yates, was as follows:—

"If any reference be made to the officers of the Medical Section, the best thing Mr. Nasmyth can do is to efface all the additions and interlineations made in the original paper (having first taken a copy of them for his own use). It could neither be desirable to him, nor to the Referees, that any new or unpublished matter should be exposed, nor can such exposure throw any light on the subject. I, for my part, shall beg to decline the reference if any writing be submitted to me, except what Mr. Nasmyth can assert existed in the paper when read to the Medical Section."

The Council then adopted the following Resolution, and requested Mr. Yates to communicate it to Mr. Nasmyth:—

"The Council having at a former meeting taken Mr. Nasmyth's application into consideration, and having referred the question to the authors of the report to the Council, dated November 16, 1840, who have been unable to give an answer on the points referred to, regret that they feel themselves incompetent to take any further step in the case*."

The members of the Council having received a printed communication from Mr. Nasmyth, dated 20th of March, 1841, addressed to themselves, a meeting of the Council was held on the 29th of March, and the following Resolution adopted:—

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* In a printed communication from Mr. Nasmyth to the Council, dated 20th of March, 1841, in which this resolution is quoted, the words "*regret that they,*" are omitted in the quotation. These words were, and still are, in the original minute which Mr. Yates was desired to communicate to Mr. Nasmyth, and were accidentally omitted by Mr. Yates in transmitting the Resolution to Mr. Nasmyth.

"The Council having for the first time had submitted to them a copy of a "document, (being a note at page 3 of a printed letter, dated March 20, "1841, signed 'Alexander Nasmyth,' and addressed to the members of the "Council of the British Association,) which document they have reason to "believe has not been seen by the Committee, together with other evidence "which they conceive to be new, and to bear upon the subject matter of the in-"quiry referred to them on the 15th of September, 1840, request the renewed "assistance of the Committee on this difficult question; and as the above new "document purports to have proceeded from the Geological Section, the "Council would request the President and Vice-Presidents of that Section to "assist the Committee in forming their judgement and making their report."

The Council requested Mr. Yates to acquaint Mr. Nasmyth of this resolution; and as it appeared from his printed letter that he entertained some erroneous views with regard to the conduct and proceedings of the Council, they also directed Mr. Yates to afford him such explanations in reply as they hoped might remove his misconceptions; and further, to state expressly, that if they were put in possession of a copy of the original memoirs, duly authenticated, they might find it proper to publish an abstract of them in a future volume; this was accordingly done in a letter to Mr. Nasmyth, read and approved by the Council.

On the 28th of May the Council assembled to receive the report of the Committee appointed by the preceding resolution (of the 29th March). After a recapitulation of the proceedings on the two former occasions, the Report proceeded as follows: viz.—

"The Council have since thought proper to request the same Committee, to whom they have added the President* and Vice Presidents† of the Geological Section of the Association at Birmingham, to inquire into the authority supposed to be given to Mr. Nasmyth's abstract by a printed document, in the shape of a printer's revise, purporting to be the report, by the Editorial Secretary, of another paper of Mr. Nasmyth's read to the Geological Section, at the same meeting of the Association, which revise, he alleges, contains the following passage, viz, '*the ivory is neither more nor less than the ossified pulp*,' and on which he founds an argument that an affirmation to that effect had been distinctly made by himself in that paper.

"The present Committee, to whom this question has been specially referred, have procured, through the kindness of Colonel Sabine, one of the General Secretaries, a certified copy‡ of the original manuscript report referred to by Mr. Nasmyth, and which it appears was drawn up immediately after the paper had been received, by Dr. Lloyd, one of the Secretaries of the Geological Section. It is as follows:"

(It is the subjoined document marked B.)

"On comparing this manuscript copy with the printed revise, as quoted by Mr. Nasmyth at p. 3 of his printed letter to the Council, it appears that several alterations have been made in the original in its progress to that stage of revision in which Mr. Nasmyth now produces it; and in particular, that the expression quoted by him in italics, as especially corroborating the fidelity of his abstract, *is not contained in it.*

"Your Committee then agreed to send the following communication to Mr. Nasmyth through their Secretary:—

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* Dr. Buckland. † Leonard Horner, Esq., Charles Lyell, Esq.

‡ A copy, certified by Dr. Lloyd, of the rough copy preserved by himself of the original manuscript.

" 'Royal Society's Apartments, May 5th, 1841.

" 'The Secretary of the Committee appointed by the Council of the British Association, on the 29th March 1841,—to inquire into the authority alleged to have been given to the report furnished by Mr. Nasmyth to the Secretary of the British Association by a printed revise, purporting to be the report of the Editorial Secretary of a paper of Mr. Nasmyth's, read to the Geological Section at the meeting of the British Association at Birmingham,—is instructed by the Committee to request Mr. Nasmyth to bring or send the original paper which he read at the Geological Section at Birmingham, to the Committee, at their next meeting, to be held at the Apartments of the Royal Society, at half past four o'clock, on Saturday, the 8th of May, under cover, addressed to the Chairman of the Committee of the British Association, Royal Society, Somerset House.'

"Your Committee again met for the purpose of receiving Mr. Nasmyth's answer, and found the following letter, addressed to the Chairman, had been sent to the Royal Society:—

" '13 A, George Street, Hanover Square, 7th May, 1841.

" 'Mr. Nasmyth begs to acknowledge the receipt of a communication, dated May 5th, from the Secretary of a Committee appointed by the Council of the British Association, on the 29th March 1841, to inquire into the authority alleged to have been given to the report furnished by Mr. Nasmyth to the Secretary of the British Association by a printed revise purporting to be the report of the Editorial Secretary of a paper of Mr. Nasmyth's, &c. Mr. Nasmyth begs positively to state that he had nothing whatever to do with the drawing up of the above-mentioned printed revise, and he takes this opportunity of distinctly repeating, that it does not merely 'purport' to be the report of the Editorial Secretary, but must actually be considered as such, having been sent to him by that gentleman precisely in the state in which it at present exists in his possession.

" 'The evidence in Mr. Nasmyth's hands, respecting the origin of this report, he has already submitted to the Secretary of the Council*, as well as all his original communications. In respect to the latter he begs to refer the Committee to two letters in Mr. Yates's possession; the one in print, dated the 17th April, addressed by Mr. Nasmyth to the Members of the Council of the British Association; the other in manuscript, dated 27th April, and addressed to Mr. Yates himself.

" 'Mr. Nasmyth is pleased to find that the question at issue, between the Council and himself, is so distinctly defined in the note to which he is at present replying; and in order that this matter may now at once be set at rest, will the Committee have the goodness, as soon as possible, to forward to Mr. Nasmyth the assurance that so soon as satisfactory proof shall have been submitted to it, that the 'printed revise' of the report in question emanated from the officer of the British Association, satisfaction shall also be immediately afforded to him by the restoration of his own report to the printed Transactions of the Association?'

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* The printed revise in question was stated by Mr. Nasmyth to Mr. Yates to have been received by him in an envelope, produced for Mr. Yates's inspection; it bore the London post mark of the 2nd of April, 1840; was directed to Mr. Nasmyth in the hand-writing of the foreman of Mr. Taylor's printing establishment, and contained the following printed sentence:— "Professor Phillips will be obliged by the immediate return of this proof to Messrs. R. and J. E. Taylor, Red Lion Court." From the date of the post mark it may be inferred that the inclosure contained in the envelope was the printed abstract of Mr. Nasmyth's geological paper referred to in his letter to Mr. Phillips of the same date (page 2). The "proof," which must have preceded the "revise" in Mr. Nasmyth's possession, has been sought in vain, as well as the manuscript from which it had been printed.

"Addressed, by desire, to the Chairman of the Committee of the British Association, Royal Society, Somerset House.

"Mr. Nasmyth having thus made no reply to their request to be allowed to see his original paper, your Committee cannot proceed further in the inquiry.

(Signed) "LEONARD HORNER, Chairman."

The Council having failed in their frequently repeated endeavours to obtain Mr. Nasmyth's original papers, or assured copies of them, for the purpose of comparison with Mr. Nasmyth's abstract, are unable, on the one hand, to publish the latter, authenticated as a faithful report of the papers read by that gentleman at the meeting at Birmingham, or, on the other hand, to decide that it is not a faithful report of those papers. They conceive that when due consideration is given to the caution proper to be exercised in sanctioning the publication of papers in a case of disputed claim as to priority of discovery;—and when it is remembered that Mr. Nasmyth's abstract, however correct it may be, was not drawn up until several months after his papers were read;—and that in the interim the discovery which he claims for himself was communicated as an original discovery by Mr. Owen to the French Institute, and published as such;—the propriety of requiring the original documents, or assured copies of them, for the purpose of authenticating the abstract, will be universally assented to.

The Council would nevertheless feel great regret, that any man of science who had favoured the Association with the communication of his researches, should think that he had reason to be dissatisfied with the way in which they were received; and as Mr. Nasmyth, while withholding the original papers, which are his undoubted property, still presses the publication of his abstract in the volumes of the Association Reports; and as the Council willingly admit that it was furnished in strict compliance (presuming its fidelity) with the request of the Assistant General Secretary, under whose superintendence the volumes are published; they have decided on complying with his request for its insertion in the present volume, though they are unable to pronounce on its fidelity. They consider it right to publish at the same time that contemporaneous report of Mr. Nasmyth's two papers read before the Medical Section, which was furnished by himself to the Editor of the Athenæum Journal, and which is now reprinted from the original manuscripts so furnished by Mr. Nasmyth, preserved by the Editor of the Athenæum, and placed by him at the disposal of the Council. To these they have added Dr. Lloyd's contemporaneous abstract of Mr. Nasmyth's paper, read to the Geological Section, which may indeed be considered to have the best claim of the three for insertion in the volumes of the Association, having been furnished, in strict conformity with the rules, by the official organ of the Geological Section. The members of the Association who take an interest in this branch of Physiological research, and wish to know what Mr. Nasmyth communicated to the meeting at Birmingham, will thus have before them the best information which it has been in the power of the Council to procure.

The Council have also thought it right to prefix to these documents a concise and continuous relation of their proceedings, which they now draw to a close, in a case of considerable delicacy and difficulty, the only one of its kind which has occurred in the history of the Association; and they hope that by an adherence to the regulations which now prescribe the early publication of the annual volume, and by an observance of the caution inserted in the circular sent to members preparatory to the meetings, to the effect that—authors of communications to the Sections will be expected, before the close of the meeting, to present concise and careful abstracts to the Secretaries of the

Sections, before which their papers have been read,—the repetition of similar cases in future will be effectually prevented.

SUBJOINED DOCUMENTS.

(A.)—*Reports of Mr.* NASMYTH's *two papers read before the Medical Section at Birmingham, furnished by himself to the Editor of the Athenæum Journal, and printed in No.* 620, *page* 707. *Sept.* 14*th*, 1839. *Reprinted from the Original Manuscripts, and showing the differences between the Manuscripts and the Reports as they appeared in the Athenæum.*

Mr. Nasmyth read a paper "On the Microscopic Structure of the Teeth," in which he treated also of the covering of the enamel and of the organization of the pulp. He first stated that his researches had led him to a conviction contrary to that of Retzius, Purkinje, and Fränkel, for he had found that the enamel in all cases possesses a distinct envelope or coating. On the incisor of the calf, and on several other simple teeth, he had also traced in it the corpuscles of Purkinje, analogous to those found in bone**. With respect to the microscopic structure of the teeth, Mr. Nasmyth treated principally of the interfibrous substance, which he said was not "structureless," as has been erroneously stated, but decidedly cellular. The fibres themselves he described as presenting an interrupted or baccated appearance, as if made up of compartments, which differ in size and relative position in various series of animals. He detailed their peculiarities in the human subject, in some species of the monkey tribe, and in the oran outan. After the earthy matter of teeth has been removed by acid, the animal residue, he stated, consists of solid fibres, and if the decomposition be allowed to continue, these fibres present a peculiar baccated appearance. The general appearance of the fibres treated by acid is similar to that of the fibres of cellular tissue generally, and the diameter of each corresponds exactly to the calibre of the dental tube, as described by Retzius, and which, according to that writer, is pervious, although at the same time he says that it is always more or less filled with contents of an earthy nature. With regard to the internal structure of the pulp, Mr. Nasmyth stated that the number of minute cells presenting themselves in its interior, in a vesicular form, is very remarkable. They vary in size from the ten-thousandth to one-eighth of an inch in diameter, and are evidently disposed in layers. The parenchyma of macerated pulp is found to be traversed by vessels, and to be interspersed with granules. The arrangement of these cells or vessels, Mr. Nasmyth thinks, may account for the shrinking or nearly total disappearance of the pulp which he has frequently observed: their use in the œconomy of the part he has not yet ascertained. They are evidently filled either with air or fluid. He finds that they [constantly]† exist on the formative surface of the pulp. Mr. Nasmyth [now]† *next** proceeded to the [most difficult department of the subject—to that which former inquirers have either evaded or treated very incompletely, viz. the]† nature of the process by which the ivory is developed. The formative surface of the pulp, which is in apposition to the ivory, and by which the latter is produced, he described as presenting a general cellular arrangement, which he denominated reticular, resembling a series of skeletons of a desiccated leaf. This reticularity is found to have peculiar diversities in different classes of animals. Mr. Nasmyth has

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** A full description of this structure [may]† *will** be found in a paper by Mr. Nasmyth, in the forthcoming volume of the Transactions of the Medico-Chirurgical Society, accompanied by drawings.

* The words in italics are in the Athenæum, but are not in the original manuscript.

† The words in brackets are in the original manuscript, but are not in the Athenæum.

found that a similar appearance is presented by the capsule and by the capsular investment of the enamel. The leaves or compartments of the reticulation are surrounded by a well-defined scolloped border, from which occasionally processes are observed to arise at regular intervals. With respect to [the actual process of]† the formation of the ivory, Mr. Nasmyth [candidly avowed]† *stated** that he was not prepared with a [perfectly]† satisfactory theory, [but could]† *and would** only submit a few observations based on his own researches. On the surface of the pulp, he said, are found innumerable detached cells, with central points, which latter are at regular intervals corresponding in extent to those existing between the fibres of the tooth. The cellules of the fragments of the ivory which are found scattered on the pulp resemble exactly in size and appearance the cellules of the latter when in a state of transition. Mr. Nasmyth is of opinion, that from the spirally fibrous frame work of the reticulations are evolved the spiral fibres of the tooth. The diameters of the two sets of fibres exactly agree. The projections on the formative surface of the pulp correspond to the centres of the cells, may be traced to belong to their structure, and are evidently fibres passing upwards from the pulp. Mr. Nasmyth has also ascertained that the fibres of perfect ivory resolve themselves by decomposition into similar granules. He has not discovered the manner in which the osseous matter is deposited in the cells of the interfibrous substance, but he has observed that these cells are subdivided into minute cellules, for they present the appearance of being filled with smaller cells in certain progressive stages of development. But in whatever aspect, said he, we view the formative organs of the tooth and the dental tissues themselves, and whether we examine the latter during the process of their developement or after their formation has been completed, we are everywhere met by appearances which denote a cellular or reticular arrangement. Mr. Nasmyth concluded his paper by a notice of Schwann's [recent]† work on the cellular character of primary tissues, dwelling [more particularly]† on his views of the cellular organization of the pulp, from which [as he showed]† his own were essentially different.

Mr. Nasmyth read a paper "On the Structure of the Epithelium," which he described as being composed of cells. He first alluded to the views of Leeuwenhoek on the subject, contained in letters to the Royal Society, written in 1674 and in 1684–5, and according to which this tissue is composed of scales. The researches of subsequent inquirers tend to prove that scales or cells of various forms exist on the surface of all mucous and serous membranes, on the inner membrane of the vascular system, &c. Mr. Nasmyth described the epithelium as a layer of substance destitute of vessels, covering the vascular surface of mucous membranes. The scales, as they were first termed by Leeuwenhoek, of which it is composed, are flat bodies, with a thick portion or nucleus in their centre, and with very thin and transparent margins, which are sometimes curved: their surface often presents numerous transparent points, with very fine lines. The nucleus of the scale generally contains a small body, which has been called the nucleus-corpuscle. If the secretion be removed from an irritated mucous membrane, these bodies are found to assume the appearance of cells; but generally at the surface they resemble scales, from having increased in size and undergone compression. In the fœtus the well-defined scales of the epidermis are not unfrequently seen externally; the *rete Malpighii* consists of newly-formed cells, and between the two may be observed other cells in a state of progressive development. In the epithelium generally, a nucleus is first [found]† *formed**, and then a cell is formed around it. These cells are connected by a gelatinous substance, interspersed with minute granular bodies, which displays considerable elasticity, and which sometimes presents a fibrous appearance. The granules can be caused to disappear by compression. In certain parts of the epithelium of the calf, distinct fibres are observed to pass over the surface of the scales, and to connect them together, thus forming a very delicate net-work. On the surface of the body and of the mucous membranes of man and animals generally, the superficial scales are thrown off by pressure from the cells beneath. But in some cases, as with frogs and efts, the epithelium-scales are removed in a continuous layer, and Mr. Nasymth is disposed to believe that it is the covering which, according to naturalists, is swallowed by the animal after having been shed. The cuticle and epithelium then are evidently organized [tissues]† *bodies**. It would appear that they are formed from a fluid secretion, and that their various stages of development are as follows: 1st, the formation of nuclei and their corpuscles; 2nd, that of cells; 3rd, the growth of the latter effected by vital imbibition; 4th, their compression and gradual conversion into minute lamellæ or scales. The cells seem to have within themselves a power of growth, and it remains for pathologists to determine what share the derangement of this function has in the production of cutaneous diseases. Under certain modifications the epithelium certainly presents vital phænomena, among which may be mentioned the ciliary motions. Mr. Nasmyth concluded his paper by an especial description of the portion of the epithelium lining the cavity of the mouth. In the fœtal subject, previous to the extrusion of the teeth, it forms on the alveolar arch a dense projecting layer, distinguishable from the surrounding membrane by its whiteness, and by superficial and waving ridges and sulci. The younger the subject, the greater is its thickness. It is made up of a mass of scales lying one above the other, and thus presents no resemblance to cartilage, though it has been generally classed as such. In the interior of its structure, where it corresponds to the molar teeth, small vesicles may be frequently observed, varying in size from one-fourth to one-eighth of a line in diameter. On microscopic examination, the [parietes]† *particles** of these are found to consist of attenuated scales, and their cavity to contain a fluid abounding in minute granules and cells. They are probably the "glands" described by Serres as intended for the secretion of the tartar. Larger vesicles are also found implanted in the vascular mucous membrane, composed of a very delicate tissue, and containing a transparent fluid, which coagulates on the application of heat or acid. In this fluid float numerous globules and scales, similar to those of the epithelium generally. The internal or attached surface of the alveolar epithelium presents numerous fringed processes, which sink into the substance of the subjacent mucous membrane. These are found to be composed of elongated scales. By immersion in water or diluted spirits of wine, these fringes are much enlarged, and their size, indeed, exceeds that of the dense epithelium itself.

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* The words in italics are in the Athenæum, but are not in the original manuscript.

† The words in brackets are in the original manuscript, but are not in the Athenæum.

(B.)—*Dr. Lloyd's Abstract of Mr. Nasmyth's Paper read before the Geological Section at Birmingham; printed from a copy preserved by Dr. Lloyd.*

"During the author's microscopic researches on the structure of teeth, he was led to the discovery of the organized nature of the interfibrous substance which Purkinje, Fränkel, Retzius, and Müller have regarded as structureless, and which he is disposed to believe is so characteristic in different animals as to be capable of affording valuable aid in the classification of the animal kingdom. This structure he first observed in a section of a fossil tooth of a rhinoceros, by the aid of a magnifying power of one-tenth of an inch focal distance, with an achromatic condenser of the light. The section presented an appearance of cells or compartments, the form of the cells varying in different animals; the structure also of the fibres of different teeth presenting an interrupted or baccated appearance; the size and relative position of these divisions of a fibre differing in various series of animals. In man, each division is of an oval form, and connected [by] their longer axes, which correspond with the course of the fibre. In some species of quadrumana, the fibre appears to consist of two parallel rows of compartments. In the orang outang, the form is rhomboidal; and in the baboon, they are oval, as in man. The laminated concentric structure of the tusk of the mammoth, the strength of ivory when cut parallel to the long axis of the tusk, and its weakness if cut at right angles, are urged in corroboration of this peculiar structure. The structure of the enamel, as seen in a section parallel to the long axis of a tooth, presents compartments of a semicircular form; the convexity of the semicircle looks upwards towards the free external portion of the tooth. The chemical composition of the enamel has hitherto led to the conclusion of there being only a small portion of animal matter in enamel. From Dr. Thomson's recent analysis it appears that this has been much understated. The pulp is observed to be cellular throughout its internal structure, and this structure is essentially concerned in the development of the ivory, in the production [of] both [the] fibres as well as of the interfibrous substance. There exists a great analogy between the internal or productive surface of the capsule and the external or productive surface of the pulp. The membranous investment of the enamel in human teeth, lately discovered by the author, displays a similar arrangement. The crusta petrosa is provided with a membranous investment.

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* The words in italics are in the Athenæum, but are not in the original manuscript.

† The words in brackets are in the original manuscript, but are not in the Athenæum.

"The above is a correct copy of my rough copy.

(Signed) "G. Lloyd[*]."

(C.)—*Mr. Nasmyth's Abstract of the Three Papers, sent to Mr. Phillips on the 24th February* 1840, *abbreviated at Mr. Phillips's suggestion, and finally corrected by Mr. Nasmyth in its progress through the Press in May* 1840. *The italics are Mr. Nasmyth's.*

1. *The Capsular Investment of the Enamel.*—The *Crusta Petrosa*, said Mr. Nasmyth, had been described after Retzius, Purkinje and Fränkel, as a layer external to the ivory of the fangs of the simple and compound teeth of man, and mammalia generally, but as not present in the simple teeth, as a covering to the enamel. Now this latter position he not only controverted, but maintained, in direct opposition to it, *that the enamel itself possesses in all instances a distinct envelope or coating*. On the incisors and other simple teeth of many animals he had succeeded in tracing, in this envelope, the corpuscles of Purkinje, analogous to those found in bone[†].

2. Mr. Nasmyth next passed to the consideration of the *interfibrous substance of the ivory*. Purkinje and Fränkel had stated that "the proper den-

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[*] The words within brackets are noticed by Dr. Lloyd as having been accidentally omitted in his original manuscript, and were since supplied by him as being necessary for the sense.

[†] In the 8th Vol. of the Med. and Chir. Transactions is a paper by Mr. Nasmyth containing a full account of his discovery of the Capsular Investment of the Enamel.

tal substance consists of a uniform structureless substance, and of fibres passing through it." Retzius, Müller and others leave us to conclude that the interfibrous substance does not present any traces of peculiar conformation. Here again he was at issue with these authorities; for he believed, and hoped he could demonstrate, both by preparations and diagrams (a great and interesting variety of which were exhibited to the Meeting), that the interfibrous substance of the ivory was not only organized, but *peculiarly and characteristically organized in different animals*, so as to be capable of affording valuable aid to the naturalist in classifying the animal kingdom. In short it was *cellular*: this he had first learnt in examining a delicate section of the fossil tooth of a Rhinoceros; afterwards he had found the same appearances in recent teeth; and subsequently in all the specimens which he had examined.

3. Mr. Nasmyth had examined the *fibres* of different teeth, and had generally found that they presented *an interrupted or baccated appearance*, as if they were made up of different compartments. The size and relative positions of the portions or divisions of a fibre differ in various series of animals. In the human subject, each compartment is of an oval shape, and its long small extremity is in apposition to the one next adjoining. The long axis of the oval corresponds to the course of the fibre. In some species of the monkey tribe, the fibre appears to be composed of two rows of compartments parallel to each other, and a trace of the same appearance is evident even in some of the principal ramifications of the fibres. (Diagrams exhibiting the peculiarities of the fibres in the human subject, the Oran-outan, the Baboon, &c., were laid before the Meeting.)

After teeth have been submitted to the action of acid, the animal residue will be found to consist of fibres in which the baccated conformation just described can at once be seen. Mr. Nasmyth here displayed numerous diagrams, showing the cells and fibres of the ivory in different stages of decomposition by acid. The diameter of the fibres he had found to correspond exactly to that of the diameter of the calibre of the tubes described by Retzius. He had decomposed the ivory in a solution of caustic potash, but had not gathered any new results from this experiment, owing to the brittle nature of the residue, the difficulty of washing it without breaking down the structure, &c.; but still the appearances displayed in this process of decomposition were such as decidedly to authorize the position, that the ivory consists exclusively of layers of cells.

4. Mr. Nasmyth stated, that having convinced himself of the peculiar cellular structure of the ivory, he had engaged, with additional interest, in the examination of the pulp, the organ by which the ivory is produced. Its external surface, he said, presented a remarkable number of minute cells, in a vesicular form, which are found on further inquiry to form the principal portion of the bulk of the pulp. The surface, moreover, has a peculiar reticular conformation (described in section 5.). The size of the vesicles of the pulp varies from probably a diameter of $\frac{1}{10000}$th part of an inch to $\frac{1}{8}$th of an inch. They are disposed in layers, and are of various shapes. Layers of macerated pulp are found to be irregular, reticulated, and interspersed with granules. Vessels in a direction which is generally vertical traverse the parenchyma. Mr. Nasmyth had frequently been struck with the rapid and frequent diminution in the substance of the pulp, which sometimes occurs. There are even cases in which it would seem to be almost annihilated, and this takes place more frequently in adult than in temporary, in otherwise healthy than in diseased teeth. Mr. Nasmyth thought this phænomenon might be accounted for by a peculiar collapse in the congeries of cells com-

posing the pulp. The contents of the cells are evidently air or fluid; but they are so extremely minute, that he had not yet been able to ascertain which. But the main feature of his position, viz. that the pulp consists throughout of vesicles or cellules, and that these exist equally in the compartments of its reticulated surface (which he should immediately proceed to describe), his researches, he apprehended, had placed beyond the reach of doubt.

5. With respect to that difficult subject, hitherto so unsatisfactorily elucidated by anatomists, *the production of the ivory* itself, Mr. Nasmyth confessed that he had long devoted himself to its examination without much success, and that even now he was far from regarding his researches as complete or decisive. The formative surface of the pulp had first engaged his attention; this he had found to present a regular cellular arrangement, which he had denominated reticular, and which may be described, he said, as resembling the skeletons of desiccated leaves. (Of this structure, both in its general appearance, its individual parts, and its particular varieties, Mr. Nasmyth exhibited numerous drawings and diagrams to the Members of the Association.) The general compartments of the reticulation are oval, and overlap each other; when insulated, their structure is seen to be curious and regular. He had first found them on the pulp of the human tooth, and afterwards on that of all other animals which he had had an opportunity of examining. The leaves of the reticulation are surrounded by a well-defined scolloped border, on which processes are occasionally observed at regular intervals. He had extended his observations to the capsule, and had found, on its formative surface, a similar reticular arrangement. Mr. Nasmyth now approached the question as to how the vesicular or cellular pulp, with its reticular and imbricated surface, was concerned in the production of the ivory. He was aware of the impossibility at present of completely describing this process, which anatomists hitherto had for the most part eluded or passed cursorily over, and should confine himself to a few facts which he had established, and which he hoped would throw some light on the subject. In the young tooth, he said, at the period of the formation of the first layer of ivory, there are found on the surface of the pulp innumerable detached cells with central points. These cells frequently form a regular and complete coating, studded with points which are placed at intervals, corresponding in extent, as it appeared to him, to those between the fibres of the adult tooth. He exhibited diagrams of layers of these cells in different stages of their transition into ivory. The points are rendered visible from the greater opacity of the intermediate material, and will be seen to absorb or reflect the light according to the difference in the focal distance. A comparison of the superincumbent perfect ivory, with the surface of the pulp beneath, is always easy (at any rate at an early stage), because portions of the former remain adherent to the latter, and fragments of the dental bone are found strewn over it, especially in human teeth. The cellular conformation of these fragments is always evident, and in size and appearance they are perfectly in accordance with the cells of the pulp. *He concluded therefore, that the ivory is neither more nor less than the ossified pulp, and that it can in no wise be regarded as an unorganized body.* That the ossification is effected by means of a peculiar arrangement of minute cellules, seems to be evident from the constant presence of granules in the body of the pulp, and on its surface; and from the subdivided appearance of the cells, when in a state of transition into perfect ivory. As almost all preceding writers had, he believed, uniformly described the ivory as a secretion from the pulp, he wished particularly to insist upon its being an organic deposition of ossific matter in

the pre-existing cells of the pulp. (Here diagrams of different layers of cells in various stages of ossific transition were exhibited to the Meeting.) The *fibres of the tooth*, as it appeared to Mr. Nasmyth, are *derived from the framework of the reticulations*: at any rate, the fibres bounding the reticulations are precisely analogous in diameter and direction to the subsequent fibres of the tooth. He exhibited diagrams also in confirmation of this view*.

6. The *laminated cellularity of the ivory*, which Mr. Nasmyth had shown was a natural consequence of the cellular structure of the pulp, was also borne out, he thought, by facts coming under daily observation, or recorded by scientific inquirers, which could not be explained by any other theory; viz. by the evidently laminated and concentric structure of the teeth of the mammoth, which is rendered directly evident during their decomposition; by the experiments of Hunter on the teeth of animals fed on madder; by the circumstance that ivory is found to possess considerable strength if cut parallel to the long axis of the tooth, and that it is weak if cut at right angles; and also by many other phænomena of frequent occurrence.

7. When the growth of the ivory is completed, the primary function of the pulp ceases; but its residue, under the influence of disease, *is often observed to ossify in different parts of its substance.* The bony substance thus formed resembles, when viewed under the microscope, the irregular ivory constituting the teeth of many of the lower animals, of fishes for instance, in which the pulp becomes entirely ossified. It consists of irregularly radiating filaments, blended with small calcigerous cells, in which ossified vessels are seen to ramify. In some animals, such as the Bradypus, Trichecus Rosmarus, Megatherium, &c., the pulp ceases at a certain period to be converted into ivory, and a peculiar and imperfect bony substance is then formed, until the whole of the pulp becomes ossified. In short, the simplest forms of teeth are almost exclusively composed of this substance; and in many of those, which consist of cement and ivory without enamel, it fills up the internal cavity. It is so frequently present, is so perfectly different from the other dental formations in the mode of its development, the nature of its function, and the appearance which it presents, that in Mr. Nasmyth's opinion it merited the appellation of the *fourth distinct constituent substance of the tooth.* It is of frequent occurrence in the human subject, but anormally, and in every case in which he had met with it, as the sequela of long-continued disease, either of the tooth itself or of some part of the mouth; but still he said it was proper to observe, that there is no direct evidence to prove that ossification of the residue of the pulp may not take place in the human subject without previous morbid symptoms.

8. The results of Mr. Nasmyth's investigations into the structure of the enamel were not quite in accordance with those of recent writers on the subject. Retzius, Purkinje and others had stated that the enamel consists of fibres running in a direction from the centre to the circumference of the tooth. On making a section of the enamel parallel to the transverse diame-

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* Before quitting this part of the subject, Mr Nasmyth alluded to the recent researches of Schwann on the structure of elementary tissues, and with respect to the connexion which that author appears only to presume to exist between the unossified pulp and the ivory already formed, quoted the following passage from page 125 of that author's work: "Against the theory that the dental substance is the ossified portion of the pulp, the facility with which the one is separated from the other has been adduced; and I allow the force of this objection. Nevertheless, it is at any rate weakened by the circumstance, that a portion of the pulp actually remains attached to the dental substance, and by the fact, that in half-ossified ribs, for instance, the cartilage can be easily separated from the ossified portion; and it must be remembered, that in the tooth the separation must be easy in proportion to the difference between the consistence of the pulp and of the dental bone."

ter of the tooth, the appearance of fibres as described by these writers was, Mr. Nasmyth allowed, distinctly evident. If, however, a different section be made, for instance, one near the surface, parallel to the long axis or vertical direction of the tooth, an appearance presents itself which had induced him to take a different view of the structure of this substance. This was *an appearance of compartments or divisions* of a semicircular form; the convexity of the semicircle or arch generally looking upwards towards the free external portion of the tooth. Several diagrams illustrating this conformation were here exhibited. In sections, both of enamel and ivory, there will always be observed, said Mr. Nasmyth, isolated cells near the margin, which admit of their form and structure being carefully studied.

All the analyses hitherto published of the chemical composition of the enamel had favoured the conclusion, that it contains only a very small portion of animal matter; but when he had detected the cells or compartments just mentioned, he could not but infer that each of these had for its basis and support a framework of animal tissue. He had accordingly immediately requested his friend Dr. Thomson, of Glasgow, to favour him with a complete analysis of the chemical composition of the different structures of the teeth in their various states of health and disease. The results of this analysis, so far as it had been proceeded with, were highly interesting. He laid them before the Members of the Association in a tabular form, observing, that with respect to the enamel, Dr. Thomson's experiments quite favoured the conclusion *that it was provided with an animal basis*, a result which, as he had just observed, he had previously arrived at by means of microscopic researches.

9. In a separate paper read before the Medical Section of the Association, Mr. Nasmyth detailed his investigations into the structure of the *Epithelium*, which he stated to be also composed of cells. Leeuwenhoek, he said, had been the first to give an accurate account of the structure of this tissue*. Leeuwenhoek stated the human epithelium and epidermis to be composed of scales, of which he has left very accurate descriptions and delineations. He alluded to the scales or cells on the mucous membrane of the mouth, which have since been proved to exist in various forms, on the surface of all mucous and serous membranes, on the inner membrane of the vascular system, &c. *The Epithelium Mr. Nasmyth defined to be a layer of non-vascular but not therefore inorganic substance covering the vascular surface of mucous membranes.* If, said he, a mucous membrane, for instance the conjunctiva, or the buccal, be slightly rubbed, the microscope will show that numerous small particles have been detached from it. At first, being flat bodies with a central nucleus (sometimes absent), and a very thin margin (sometimes curved), they present the appearance of scales, as they were denominated by Leeuwenhoek. Their surface often presents numerous transparent points with very fine lines. The nucleus generally contains a small body, the nucleus-corpuscle. These so-called scales, when removed from an irritated mucous membrane, are found to be smaller and more globular; they have then the usual nucleus and nucleus-corpuscle, but the surrounding structure is smaller, and in the form of a cell. Here and there, too, the nucleus and its corpuscle are seen to be isolated. In a section of the epithelium and mucous membrane numerous nuclei are found in apposition to the latter, which, more externally, are surrounded by a cell, whilst at the surface, this cell, compressed, assumes the appearance of a scale. In the layer of epithelium, from the under surface of the tongue of the calf, these bodies in their various stages of granules, cells and scales, may be well seen, according as the object is removed from or ap-

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* See his Letters to the Royal Society, which may be found in the 3rd and 4th volumes of his collected works.

proximated to, the microscope. (Numerous diagrams illustrating these various stages were laid before the Meeting.)

In the fœtus, the defined and well-formed scales of the epidermis are not unfrequently distinctly seen externally; the *rete Malpighii* consists of newly formed cells, and between the two may be observed other cells in a state of progressive development. On the surface of the vascular mucous membrane *minute cells are found with a nucleus internally, round which the cells grow, and this in short is the process of development of the epithelium.*

With respect to how the epithelium cells are connected together, a subject which had not yet been discussed, Mr. Nasmyth stated, that on the surface of the mucous membrane, the considerable spaces between them are occupied by a gelatinous substance, interspersed with minute granular bodies. This same substance also fills the minute linear intervals between the superficial scales. (Diagrams were exhibited showing the arrangements in both these cases.) The gelatinous medium is considerably elastic, as may be seen under the microscope, on attempting to draw asunder the scales of the moist epithelium. The scales towards the free surface distinctly overlap. The granules of the gelatinous medium give to the epithelium, *en masse*, an appearance of density as they sometimes cover the scales, but can be separated from the latter, and indeed made to disappear entirely by compression. In certain parts of the epithelium of the calf, distinct fibres pass over the surface of the scales and connect them together, thus forming a very delicate network, which is very evident on compression of the thick epithelium on the anterior part of the alveolar arch of the upper jaw.

On the skin and surface of the mucous membranes of man and animals generally, the external layer of scales is continually being thrown off, in consequence of pressure from those in process of development from beneath; after cuticular lamellæ have been detached, their place is regularly occupied again by newly formed scales. In some cases the external layer of cuticle is removed, not scale by scale, but in a continuous form. The cuticle of the frog is composed of minute scales, not overlapping, but in direct apposition, forming one lamina of a beautiful, continuous, tessellated appearance. This is thrown off at once from the entire bodies of frogs and efts. (Mr. Nasmyth here displayed to the Meeting considerable portions of such a cuticle, stating it to be his opinion, that this is the skin which is described by some naturalists as being swallowed as soon as thrown off.) On a microscopic examination of the skin of the frog, cells will be found internally, which gradually change into the shape of scales, as they become more external, in the same manner as has been described above.

Mr. Nasmyth could not but conclude, from a consideration of the phænomena just described, *that the cuticle and epithelium are organized tissues, which are formed, as it appeared to him, from a fluid secretion on the surface of the chorion; the various stages of development being, first, the formation of nuclei and corpuscles; second, that of cells; third, the growth of the latter effected by vital imbibition; fourth, their compression and gradual conversion into minute lamellæ or scales.* It appeared to him a rational conclusion, that the component parts of the cuticle and epithelium have within themselves a power of growth; it remained for pathologists to determine what share the derangement of this function has in the production of cutaneous diseases. The ciliary motions and other vital phænomena furnish new arguments for the organic nature of the epithelium.

Mr. Nasmyth concluded his paper by an especial notice of *the epithelium of the mouth.* In the fœtal subject, previous to the extrusion of the teeth, this forms on the alveolar arch a dense, projecting layer, distinguishable by its whiteness, and by waving and irregular ridges and sulci on its surface. The younger the subject, the thicker is this epithelium. It is most prominent over the molar teeth; its internal surface is concave, receiving the projecting mucous membrane; it is constituted by a mass of scales, superimposed on each other; and hence the terms "dental cartilage," or cartilage of the gum, which have hitherto been applied to this structure, give an erroneous idea of its true nature; for cartilage always presents the corpuscle discovered and described by Purkinje. Here, as in other portions of the epithelium, (except on the surface of the vascular mucous membrane, which presents simple cells with their corpuscles,) the external scales are the largest. In the interior of this alveolar epithelium, where it corresponds to the molar teeth, small vesicles may be frequently observed, varying in size from a quarter to an eighth of a line in diameter. To the naked eye they are transparent; under the microscope their parietes are found to consist of attenuated scales, and their cavity to contain a fluid abounding in minute granules or cells. The internal surface of the alveolar epithelium frequently presents concavities, from a line and a half to three or four lines in circumference, corresponding to projections from the mucous membrane, formed by a larger species of vesicle, which is deeply implanted in the vascular mucous membrane. The parietes of these vesicles are delicate membranes; they contain a transparent fluid, coagulable by heat, acid, or spirit, in which float numerous globules and scales similar to those of the epithelium generally. The external surface of the alveolar epithelium presents, after a slight maceration, numerous fringed processes, measuring from one line to one line and a half in length, and half a line in breadth. Under the microscope these fringes are found to be composed of elongated scales connected together, forming masses, which divide and subdivide, until they attain such an extreme tenuity, that the most minute terminations consist but of two scales, in marginal apposition. If the epithelium be carefully separated from the surface of the mucous membrane corresponding to the unextruded molar teeth, and placed in water, or in diluted spirit of wine for some little time, its external surface presents these fringes much enlarged, and forming a mass more considerable in size than the dense epithelium itself.

MATHEMATICS AND PHYSICS.

On the relation of Sturm's Auxiliary Functions to the roots of an Algebraic Equation. By Professor SYLVESTER.

The author availed himself of the present meeting of the British Association to bring under the more general notice of mathematicians his discovery, made in the year 1839, of the real nature and constitution of the auxiliary functions (so-called) which Sturm makes use of in *locating* the roots of an equation: these are obtained by proceeding with the left hand side of the equation and its first differential coefficient as if it were our object to obtain their greatest common factor; the successive remainders, with their signs *alternately* changed and preserved, constitute the functions in question. Each of these may be put under the form of a fraction, the denominator of which is a perfect square, or in fact the product of *many*: likewise the numerator contains a huge heap of factors of a similar form.

These therefore, as well as the denominator, since they cannot influence the series of *signs*, may be rejected; and furthermore we may, if we please, again make every other function, beginning from the last but one, change its sign, if we consent to use changes wherever Sturm speaks of continuations of sign, and *vice versâ*.

The functions of Sturm, thus modified and purged of irrelevancy, the author, by way of distinction, and still to attribute honour where it is really most due, proposes to call "Sturm's Determinators," and proceeds to lay bare the internal anatomy of these remarkable forms.

He uses the Greek letter "ζ" to indicate that the squared product of the differences of the letters before which it is prefixed is to be taken.

Let the roots of the equation be called respectively $a, b, c, e \ldots l$, the determinations taken in the inverse order are as follows:—

$$\zeta\,(a, b, c, e \ldots l).$$

$$\Sigma\,\zeta\,(b, c, e \ldots l)\,x - \Sigma\,a\,\zeta\,(b, c, e \ldots l).$$

$$\Sigma\,\zeta\,(c, e \ldots l)\,x^2 - \Sigma\,(a + b)\,.\,\zeta\,(c, e \ldots l)\,x + \Sigma\,a, b\,.\,\zeta\,(c, e, \ldots l).$$

* * * * * * *

$$\Sigma\,(\zeta\,(k, l)\,(x - a)\,(x - b)\,(x - c)\,(x - e) \ldots (x - h)).$$

It may be here remarked, that the work of assigning the total number of real and of imaginary roots falls exclusively upon the coefficients of the leading terms, which the author proposes to call "Sturm's Superiors:" these superiors are only *partial* symmetric functions of the *squared differences*, but *complete* symmetric functions of the *roots themselves*, differing in the former respect from those other (at first sight similar-looking) functions of the squared differences of the roots, in which, from the time of Waring downwards, the conditions of reality have been sought for. It seems to have escaped observation, that the series of terms constituting any one of the coefficients in the equation of the squares of the differences (with the exception of the first and last) each admit of being separated and classified into various subordinate groups in such a way, that instead of being treated as a single symmetric function of the *roots*, they ought to be viewed as aggregates of many. In fact, Sturm's superior No. 1. is identical with Waring's coefficient No. 1; Sturm's superior No. 2. is a *part* of Waring's coefficient No. 3; Sturm's superior No. 3. is a *part* of Waring's coefficient No. 6; and so forth till we come to Sturm's final superior, which is again coextensive and identical with the last coefficient in the equation of the squares of the differences. The theory of symmetric functions of forms which are themselves symmetric functions of simple letters, or even of other forms, the author states his belief is here for the first time shadowed forth, but would be beside his present object to enter further into. He concluded with calling attention to the importance to the general interests of algebraical and arithmetical science that a searching investigation should be instituted for showing, *à priori*, how, when a set of quantities is known to be made up partly of possible and partly of *pairs* of impossible values, symmetrical functions of these, one less in number than the quantities themselves, may be formed, from the signs of the ratios of which to unity and to one another the respective amounts of possible and impossible quantities may at once be inferred: in short, we ought not to rest satisfied, until, from the very *form* of Sturm's Determinators, without caring to know how they have been obtained, we are able to pronounce upon the uses to which they may be applied.

On the Theoretical Computation of Refractive Indices. By Prof. POWELL.

In the Report on Refractive Indices which the author had presented to the Association, his professed object extended only to exhibiting the results of *observation*, without any reference to *theory*. That the comparison of these results with theory is highly important is indeed manifest; and the necessity for it is dwelt upon (in reference to the Report just mentioned) in the address of the General Secretaries at the meeting of 1840. It would, however (on several grounds), have been foreign to the design of that Report to have introduced the subject of *theoretical* computation. The author has since that period been devoting his attention to this latter subject; and it is the object of the present communication to state very briefly the progress made in it. The results in the Report on Indices are classified under three heads: 1st, those of Fraunhofer; 2nd, those of Rudberg; 3rd, those derived from the *latest* observations of the author, comprising many *new* results, *superseding* former ones, and others, the combined results of several sets of earlier observations compared with later. The 1st series was compared with theory, 1st, by the author in the Phil. Trans. 1835, but only by an approximative and tentative method; 2ndly, by Mr. Kelland, by a direct and exact method in the Camb. Trans., vol. vi.; 3rdly, for the rays D and C only, by Sir W. R. Hamilton, in the Phil. Mag., 3rd Series, vol. viii.;

4thly, by M. Cauchy, in the 'Nouv. Exerc.,' livr. 3—6, by a most exact and elaborate process. The 2nd series has been computed only by the author, by the same approximative method as the 1st, in the Phil. Trans. 1836, whence it was reprinted in Poggendorff's 'Annalen.' Some of the first results belonging to the 3rd series were computed by the author, by Sir W. R. Hamilton's method, in the Phil. Trans. 1837; and three of the higher cases, in which discrepancies appeared, were recomputed by Mr. Kelland's method in the Phil. Trans. 1838. Thus it was desirable to recompute series 2. by an *exact* method, and necessary to calculate all the *new* and *improved* results of series 3. This the author has now done, by means of Sir W. R. Hamilton's formula, and for the sake of uniformity has included series 1. The results agree perfectly with observation, *except in the most highly dispersive cases*. But here it is found, that if an *empirical change be allowed in one of the constants* for each medium, a sufficiently close accordance is obtained.

On the Refraction of Heat. By Prof. POWELL.

In a short communication to the Physical Section of the British Association, 1840, the author alluded to that singular result of the undulatory view of dispersion —the existence of *a limit to all refraction* in each medium, at no very great interval below the least refrangible end of the visible spectrum; and suggested the comparison of observations on the refraction *of heat* with this conclusion. He has since followed up that suggestion, in reference to the only medium as yet examined in which it is practicable to compare the refractions of light and of heat, viz. rock-salt. In his Report on Radiant Heat, he has stated Prof. Forbes's indices for the different kinds of heat, corrected according to the Professor's own suggestion from the approximate form in which they were at first given. The proposed correction, however, allows of some latitude; and, on reconsideration of the subject, as before stated, it appears to the author most fair to take Prof. Forbes's result for light as obtained with the Locatelli lamp. This corrected by — ·04, gives for the mean light $\mu = 1{\cdot}558$, which agrees sufficiently with the author's own observations conducted by a totally different method (see Report on Refractive Indices, 1839). With the same correction, the extreme index for the *least refrangible* kind of heat is $\mu = 1{\cdot}528$. By *theory* the author has computed the value of *the limiting index* above mentioned, and finds it to be $\mu = 1{\cdot}5277$; also the index for a mean ray of heat whose wave-length is ·000079 inch, is found to be $\mu = 1{\cdot}529$. Considering that Prof. Forbes allows some uncertainty in his results, this affords a very satisfactory confirmation.

On certain Points of the Wave-Theory of Light. By Prof. POWELL.

At the Birmingham meeting of the British Association the author offered a short communication relative to certain difficulties connected with the equations of motion on which the wave-theory is now founded, which had given rise to some controversy. Since that time, however, he conceives the main difficulties have been completely cleared up; it was his endeavour to put the chief part of the subject, in this elucidated point of view, in a paper in the Philosophical Mag., March 1841, and he has since been engaged in embodying these and other points in a separate work. The whole theory of the dispersion is referred to the primary equations of motion, originally suggested by M. Navier, agreeably to the principles of M. Cauchy, since improved upon by others. The forms assumed by these equations, in connexion with the symmetrical or unsymmetrical arrangement of the etherial molecules, have a direct relation to the occurrence of rectilinear or elliptic vibrations, a distinction first pointed out by Mr. Tovey. When the arrangement is symmetrical, the existence of axes of elasticity (discovered by Fresnel), as well as the general investigation of the wave-surface, has been shown by Sir J. Lubbock to be deducible from the same primary equations; and the difference in form between the wave-surface equations of Fresnel and of Cauchy is traceable to differences in the forms of the same equations. (A synopsis of the principal formulæ referred to accompanied the paper.)

Results of some Investigations on the Phænomena of Thin Plates in Polarized Light. By the Rev. Professor Lloyd, *F.R.S.*

Professor Lloyd stated, that his attention had been drawn to this subject by a letter which he had recently received from Sir David Brewster, describing a large class of hitherto unobserved phænomena. Sir David Brewster having expressed his desire, in this letter, to know whether the wave-theory could furnish an explanation of the facts which he had observed, Prof. Lloyd was thus led to undertake the investigation which formed the subject of the present communication.

Mr. Airy had long since inferred, from a consideration of the form of Fresnel's expression for the intensity of reflected light, that when light, polarized perpendicularly to the plain of incidence, was incident upon a thin plate bounded by media of unequal refractive powers, a remarkable change in the reflected light should take place, when the angle of incidence was intermediate to the polarizing angles of the two surfaces of the plate. This theoretical anticipation was fully verified by experiment. When a lens of low refracting power was laid upon a plate of high refracting power, the rings which were formed appeared with a *black centre*, when the angle of incidence was less than the polarizing angle of the low refracting substance, or greater than the polarizing angle of the high refracting substance; while, when the incidence was intermediate to these two angles, the rings were *white-centred*, and the whole system was *complementary* to what it had been before. At the polarizing angle itself the rings disappeared, there being no light reflected from one of the surfaces of the plate, and therefore no interference.

The examination of this subject has recently been resumed by Sir David Brewster; and he has repeated the experiments of Mr. Airy in a more general form, the incident light being *polarized in any plane*. He has thus been led to many new results. The rings are found to *disappear* under circumstances in which light is reflected from *both* surfaces of the plate; and there are many remarkable peculiarities in the transition of the rings into the complementary system.

It was to the theoretical explanation of these phænomena that Prof. Lloyd now invited the attention of the Section. In the conduct of the investigation he has generalized the methods followed by M. Poisson and Mr. Airy on the same subject. The incident vibration being resolved into two, one in the plane of incidence, and the other in the perpendicular plane, each portion will give rise to an infinite series of reflected vibrations, into which it is subdivided at the bounding surfaces of the plate. The expression of the resultant intensity, for each portion, being then deduced, the actual intensity of the reflected beam is the sum of these intensities; and it is found that the *part dependent on the phase will vanish*, and therefore the rings disappear, when the plane of polarization is connected with the incidence of the following formula:—

$$\tan^2 \gamma = -\frac{\cos(\theta - \theta')\cos(\theta' - \theta'')}{\cos(\theta + \theta')\cos(\theta' + \theta'')};$$

in which θ is the angle of incidence on the first surface; θ' the angle of refraction at first surface, or the angle of incidence on second; and θ'' the angle of refraction at second surface.

On Simultaneous Changes of the Magnetic Elements at Different Stations. By the Rev. Professor Lloyd, *F.R.S.*

Professor Lloyd laid upon the table of the Section a series of curves prepared by Lieut. Riddell, representing the simultaneous changes of the magnetical elements, observed at Toronto, Dublin, Brussels, Prague, Milan, St. Helena, and Van Diemen's Land, on the 29th of May and 29th of August 1840.

He said, that one of the chief objects kept in view in the arrangement of this great system of combined observation now in operation, was the extension of the plan of simultaneous observations at short intervals of time, first laid down by Gauss. The results of this system had been, that the observed changes of the magnetical elements were strictly simultaneous at the most remote stations at which observations had been hitherto made; and that these changes followed in all cases the same laws, the representative curves being similar to one another in all their inflexions, and differing only in the magnitude of the change. This similarity had been found to extend to the utmost limits of Europe, and to hold at stations as remote as Dublin, Petersburg, and Milan. It became therefore a question of great interest in the extension of this system to still more distant stations, to determine whether there were any, and what limits to this accordance. This question was determined by the very first results of the observations recently established by the British Government; and the observations now laid before the Section were selected as elucidating it in a very marked manner. These observations were those of the declination and horizontal magnetic intensity observed at Brussels, Milan, Prague, Toronto, and St. Helena, on the 29th of May 1840; and at Dublin, Toronto, St. Helena, and Van Diemen's Land, on the 29th of August of the same year. The magnetical disturbances which occurred on these days were among the most considerable which had been as yet observed. On the former days the declination at Toronto underwent a sudden change, amounting to 1° 52′ in about twenty minutes of time, while the disturbance of the horizontal force was so great as to carry the magnet beyond the limits of its scale. On the latter day, the greatest change of the declination amounted to 1° 26′ at Toronto, and to 1° 18′ at Dublin. The greatest change of the horizontal intensity at the former station amounted to ·′028, or about $\frac{1}{36}$th part of the whole intensity; while at Dublin the change was even greater, and extended beyond the scale of the instrument. It is probable that an attentive comparison of the curves may lead to many important results; but there are some which appear upon a cursory inspection, which Mr. Lloyd said that he should now notice. The first of these was, that the greater magnetic disturbances appeared to be synchronous at the most distant stations. This important fact is exhibited much more evidently in the changes of horizontal intensity than in those of declination; and, if verified by further comparisons, leads to the conclusion, that the principal forces which disturb the magnetic equilibrium of the earth are not of local agency. The next circumstance which merited attention was, that the order of the changes was no longer regulated by the same law, at very remote stations; the representative curves exhibiting none of that similarity already referred to, which was shown within the limits of Europe, and the epochs of the successive maxima and minima presenting no agreement whatever. This important fact was first brought to light in the course of a series of simultaneous observations, made by Professor Bache at Philadelphia, and by himself at Dublin, in November 1839, in the hope of determining differences of longitude by means of the corresponding movements of the magnet at the two stations. The changes observed in the observations at present under consideration were, however, far greater in magnitude, and placed the phænomenon in a much stronger light. The last circumstance to which Mr. Lloyd invited the attention of the Section was, that the curves of horizontal intensity presented a much nearer agreement at remote stations than those of declination; from which it may be inferred, that a true knowledge of the nature and laws of the disturbing causes will be better attained by the examination of intensity changes (including, of course, those of the vertical intensity) than of those which are dependent solely on the direction of the acting forces. There were many other points of minor interest suggested by the examination of these curves; such as the appearance of a correspondence in some of the minuter changes at all the stations, although the resemblance in the greater changes was obliterated. If this should prove to be anything more than a mere fortuitous coincidence, the result might be expected to lead to some important conclusions with regard to the acting forces.

Professor Lloyd then laid upon the table the curves representing the changes of magnetic declination, observed at Cambridge University (Massachusetts) by Mr. W. C. Bond, on the term-days of May and October 1840. The corresponding observations made at the magnetical observatory at Toronto, by Lieut. Riddell, were laid down in a curve, in connexion with the latter. The results exhibited the same close agreement in the forms of the curves, and in the epochs of the successive maxima and minima, as had been already noticed in Europe, although (as before remarked) all resemblance between these and the European system of changes is nearly obliterated. New Cambridge is distant about 500 miles from Toronto; the mean declination there is 9° 20′ west.

On Sea Compasses. By the Rev. T. Dury.

In this communication Mr. Dury stated some of the results to which the Rev. Dr. Scoresby, in the continuation of his magnetical researches, has arrived, and which, with Mr. Dury, he had lately the honour of submitting to his Royal Highness Prince Albert. The points treated of were—

The defective condition of ordinary needles employed in sea-compasses, and the method used by Dr. Scoresby to test their condition, by applying them to a highly-magnetized hardened bar of the best cast steel.

The nature of the needles which Dr. Scoresby recommends to be substituted for the former. They are hardened throughout, and previous to being used, are tested by being applied to the bar already mentioned.

The application of delicate needles and large bar-magnets to measure the thickness of rocks, &c., and other materials, in mines, railway tunnels, &c.

The construction and method of magnetizing of a pair of bar-magnets, containing 192 thin steel plates fourteen inches long and one and a half inch broad, bound together with tape. They are very unusually powerful.

On the Influence of Mountains on Temperature in the Winter in certain parts of the Northern Hemisphere. By THOMAS HOPKINS.

It was stated by Mr. Hopkins, that between the latitudes of 40° and 70° north, there is in the same parallels a great difference of temperature, particularly in the winter, amounting in some cases to as much as 40° or even 50° of Fahrenheit. The western coasts of the two continents are much warmer than the eastern, and as the winds generally blow from the sea to the western coasts, it has been inferred, that the prevailing winds passing over sea to the western coasts, and over land to the eastern, was the cause of the difference in the temperature. This inference is not, however, in accordance with facts, as the low temperature is not proportioned to the distance from the western coast.

Hadley's theory represents the tropical atmosphere as rising and flowing over at the top towards the polar regions, and returning when cooled, flowing along on the surface of the earth. This inequality of temperature in the atmosphere would cause an upper current to flow north, and an under current to flow south. But the unequal velocities of the different parts of the earth's surface from the equator to the pole modify the course of these currents, and make the upper a south-west and the lower a north-east current, as shown by lines on a Mercator's chart.

This theory, true in its leading principles, does not account for what occurs on the earth's surface, because it does not take in all the causes that are in operation, which causes materially modify the general results.

The Polar current, in flowing from the north-eastern part towards the south-west, meets with elevations of the land, and is consequently, along a diagonal stripe in the direction of the general currents, obstructed in its progress, and sometimes stopped, and obliged to turn back as an upper current towards the pole; while beyond the obstruction, nearer to the equator, the tropical or upper current not being met by a polar current along this line, flows towards the obstruction, from whence it returns, partially cooled, as an under current.

In the New world, the ridge of mountains which extends from Mexico by the Rocky Mountains to the Frozen Ocean, crosses the diagonal line of the great atmospherical currents, and constitutes such an obstruction as that described.

In the Old world similar ridges extend from the southern point of the Himalaya Mountains to the Swiss Alps, including the range of the Himalaya, Hindoo Koosh, Central Asia, Armenia, Circassia, the Carpathian Mountains, and the Illyrian and Swiss Alps, and the climates found to the north-east of these chains are materially different from those which exist to the south-west.

The greatest differences of climate in those parts are found in the beginning of winter, and are, it is presumed, caused by the different quantities of atmospheric steam condensed in the respective parts.

Over the tropical seas a quantity of steam exists in the atmosphere sufficient to give a dew-point of 80°, making the steam one forty-eighth part of the whole atmosphere. This steam, which if all condensed into water, would give a depth of about nine inches, is regularly carried in the autumn and the beginning of the winter, when the northern hemisphere is cooled, from the tropical regions in a north-east direction towards the polar regions, or towards some obstructing elevation of the land, and is to a great extent condensed; and to its condensation we are to look for the great differences of winter climate in the same latitudes of the northern hemisphere.

The steam in the tropical regions of the Pacific Ocean that flows towards the north-east, with the south and south-west winds that prevail in those parts, is carried to the American ridge, and is there condensed. The result is, that the south-west side of this chain of mountains is wet and warm in the winter, from the tropics to Nootka Sound, and still further north. Captain Cook, Lewis and Clarke, Captain B. Hall, and Humboldt, describe the climate of this part in such terms as can leave no doubt of the fact. But beyond this ridge to the north-east we have a different climate in the winter, one as remarkably cold and dry as that on the other side is wet and warm. Captain Parry, Captain Back, and Lewis and Clarke, represent the country in the winter from the shores of the Frozen Sea to the Missouri as very cold and generally dry. Here we trace the effects of the condensation of steam, and of its absence, on the climates of these parts.

In the Old world the same causes produce the same effects. On the south-west sides of the various ridges of mountains, the weather is in the autumn and early part of winter very wet and warm for the latitudes. This is particularly seen in Hindoostan and the south-west coast of Italy, while to the north-east of these mountains the climate is cold and dry, over Poland, Russia, Central Asia, and Siberia.

The very heavy rains which fall to the south of the Himalaya Mountains indicate the great condensation of steam that takes place in that part of the world; and the effect produced on the climate is remarkable. The valleys are habitable to a great elevation; and Major Archer states that wheat is grown at a height of 13,000 feet in latitude 32° north, whilst Humboldt represents 1300 feet as the greatest height at which wheat can be grown in Teneriffe, a place four degrees more south. But when the steam that is in the atmosphere is all, or nearly all, condensed against the sides of elevated ridges, it is evident that it cannot carry its warming influence further north. Hence the part of the globe between these ridges and the polar regions will, in the autumn and winter, be dry and very cold.

In continuation, the author illustrated his views by supposing cases of great changes of the elevation of land and the distribution of land and water on the globe.

From the whole inquiry he concludes, that the relative situations of land and water are not the cause of the great differences of climate in corresponding latitudes; but that the great differences in the winter climates of certain parts of the northern hemisphere are attributable to elevations of land intercepting and condensing atmospheric steam, and thus rendering certain parts wet and warm, while cutting off the supply from more northern parts leaves them dry and cold.

On the Temperature of the Air in York Minster. By JOHN PHILLIPS, *F.R.S., G.S.*

It may be remarked, that the vastness and loftiness of the interior of York Minster render the air within it, in a great degree, free from violent local draughts, and yet subject to a continual gentle circulation. At the time when the observations now to be noticed were made, there was no heating apparatus in the church: the lights used were a few scattered tapers. The observations were made in the interval from April 8, 1808, to July 31, 1811. There is an interruption from April 27 to May 21, 1810, owing to the absence of the observer, and a few single days are left without observation. From April 8, 1808, to July 12, 1808 (inclusive), the hour of observation is not given. Afterwards it is given for each day, the hours varying from 11 to 5; the far greater number are taken at about 1, and a sufficient proportion about 2 and 3, to render the mean of the whole about 2 P.M., or nearly the epoch of maximum daily temperature in the open air. The observations are registered to half and one-fourth degrees, and, as far as can be judged from inspection, appear to be very faithfully recorded. The following are the deductions:—1. The comparative mean annual temperature within and without York Minster. 2. The comparative mean monthly temperature of the interior of York Minster, and the mean monthly, and mean maximum monthly temperature of the surrounding atmosphere. 3. The comparative epochs of mean annual temperature for the same conditions.

TABLE I.

Mean temperature of the air without the church...............	for forty months, deducting the last four............	49·2433
	for ditto, deducting the first four	49·1316
	Mean........................	49·1874
Mean temperature of the air within the church...............	for the same forty months, deducting the last four	49·5833
	for ditto, deducting the first four	49·7711
	Mean.........................	49·6772
Air within the Minster warmer than without..................................		0·4898
General mean temperature of York for twenty-five years		48·2000

TABLE II.

	Mean Temperature within.	Mean Temp. without, in same Months.	Approximate mean max. Temp. without.
January	36·68	33·39	44·7
February.........	39·03	39·01	46·25
March	43·14	42·91	49·3
April	45·74	48·20	55·9
May...............	53·77	57·01	64·0
June...............	58·22	61·18	72·3
July...............	61·22	62·42	73·0
August	62·52	63·51	73·4
September	59·82	57·26	66·1
October	52·18	47·81	58·2
November	44·40	40·81	51·3
December	40·52	36·43	46·4

It appears that from nearly the end of March to nearly the end of August, the air within the Minster is colder than the mean temperature of the air without; and from nearly the end of August to nearly the end of March, it is warmer. The excess of warmth rather exceeds the deficiency, and the epochs of mean annual temperature are retarded, probably about twelve days, within the Minster,—a result which may be compared with some of the conclusions arrived at by M. Quetelet and Professor Forbes in the prosecution of experiments on subterraneous temperature at small depths.

Further Researches on Rain at York, by JOHN PHILLIPS, *F.R.S., and at Harraby, near Carlisle, by* JOSEPH ATKINSON, *Esq.; with Remarks by Prof.* PHILLIPS.

At previous meetings of the Association Mr. Phillips had laid before the Section a considerable series of experiments on the quantities of rain received on equal horizontal areas, at different heights from the ground, and presented as a general view connecting the results, that each drop of rain grows continually larger as it descends through atmospheric strata successively warmer, itself being cold enough to condense on its surface the invisible vapour of water which exists in the air. On this occasion he brought forward some recent experiments, partly his own, and partly made by Mr. Atkinson, from which it might be inferred, that in the further prosecution of this subject, and in the registration of the quantity of rain for any purpose requiring exactness, special care should be taken to choose an unexceptionable situation, and to employ gauges suitable to the object proposed. The statement made by Mr. Phillips at the Glasgow Meeting, of the diminution of the measured quantities of rain, at the small heights of three, six, and twelve feet above the surface, was fully borne out and confirmed by an extract from Mr. Atkinson's register for 1841. Omitting in this year the snowy month of January, we abstract the following measurements of the rain received in *funnel-gauges* of the usual kind, at Carlisle, on the ground, and at three feet and six feet above:—

	On ground.	3 feet above.	6 feet above.
February	1·569	1·477	1·249
March	2·728	2·571	2·407
April	2·587	2·576	2·429
May	2·406	2·261	2·172
June	3·380	3·405	3·243
July to 24	3·136	3·064	3·032
	15·806	15·354	14·332

In contrast with this, Mr. Phillips presented the following table of measures of rain, received on *globular gauges* (first recommended by the Rev. Dr. Robinson at the Newcastle Meeting of the Association in 1838), at York, on the ground, and three, six, and twelve feet above. A column is also added of the quantity received in a *funnel-gauge*, three feet above the ground:—

	Globular gauge, ground.	Funnel-gauge, 3 feet.	Globular gauge, 3 feet.	Globular gauge, 6 feet.	Globular gauge, 12 feet.
April	·563	·309	·567	·579	·609
May	·910	·418	·910	·898	·947
June	·570	·315	·584	·575	·633
July to 11	·862	·436	·896	·882	·926
	2·905	1·578	2·957	2·934	3·115

By this table it appears, first, that on the average the globular gauges receive nearly twice as much rain as the horizontal funnel-gauge; secondly, that from the ground to a height of six feet, the quantity in those gauges seems not decidedly to vary, beyond limits which may be permitted by small errors of the instrument, or local irregularities; thirdly, that at a height of twelve feet *more rain* is received than at any of the stations nearer the ground. This singular result the author is at present disposed to view as due to a purely local cause; the situation of the gauges being such, that the lower gauges may be believed to be partly sheltered from the wind by shrubbery, and in consequence, during wind, the rain drops be supposed to fall upon them, in lines deviating less from vertical lines than on the upper gauge. The consequence of such conditions on *such gauges* would be as the experiments indicate. Mr. Atkinson had previously begun to employ in his series one globular gauge of twelve inches diameter, at a height of six feet; and at this same height he had placed one horizontal funnel-gauge of twelve inches diameter, another of 18 inches diameter, and a third funnel-gauge of twelve inches diameter, with the opening inclined 45°, and turned constantly to face the wind. The comparative quantities received by the twelve- and eighteen-inch horizontal, and the twelve-inch inclined gauges, appear as follows:—

	Horizontal 12-inch funnel.	Horizontal 18-inch funnel.	Inclined 12-inch funnel.
1841. January	2·364	2·129	2·668
February	1·249	1·167	1·681
March	2·407	2·153	3·550
April	2·429	2·324	2·915
May	2·172	2·074	2·436
June	3·243	3·013	3·193
July	3·032	2·777	2·531
	16·896	15·637	18·973

Supposing the graduations employed in the registration correct, the larger gauge received the smaller proportionate quantity of rain,—an unexpected result, which deserves confirmation. It appears also that the gauge inclined 45°, and turned to the wind, received more rain than the horizontal gauge; and that the quantity collected in the globular gauge was about intermediate between that of the twelve-inch horizontal and inclined funnels. From this Mr. Atkinson imagined, that its indications were more nearly proportioned to the real quantity of rain than either of the others; but it probably did not expose a sufficient arc (it should be 270°). Having pointed out these circumstances affecting the true meaning of correctly-observed rain-registers, Mr. Phillips drew attention to the importance, in all these inquiries, of a knowledge of the angle of inclination of descending rain in each shower, and concluded by proposing, as a fit general form of experimental research, so far as the mere question of the *quantity* of rain falling through given sections of air at different heights was concerned, that there should be placed in some very unexceptionably open situation a series of gauges at different heights above the surface (0, 3, 6, 12, 24 French feet), of *three kinds* at each height, viz. an ordinary *funnel*-gauge with horizontal edge; a *globular* gauge; an *azimuth- and inclination*-gauge, such as was described by the Author, and illustrated by figures in the account of the proceedings of the Section at Glasgow.

Notice of a Meteorological Journal for the Year 1840, *kept by* JOHN CAMPBELL LEES, *at Nassau, New Providence.*

Letter from the late Capt. Hewett to Capt. Beaufort, R.N. (referred to in a communication by Professor Whewell).

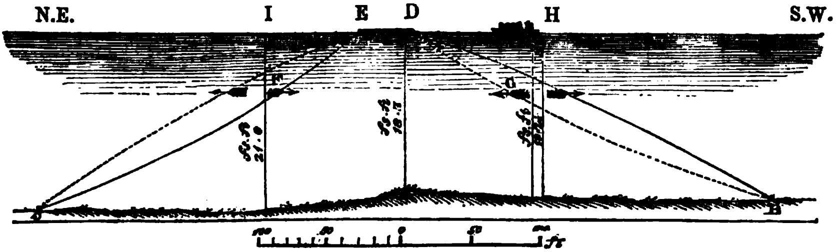
H.M. Ship Fairy, Harwich, August 31st, 1840.

SIR,—On the 24th inst., being in lat. 52° 27′ 30″ N., long. 3° 14′ 30″ E., with light breezes and smooth water, I deemed it a fitting opportunity for making a further trial on the rise and fall of tide in the middle of the North Sea; and although I was then many miles both to the northward and eastward of the spot near which Mr. Whewell had previously expressed his wishes that the experiment should be made, yet I thought that if good observations by any means could be obtained at the above position, they would at the least serve to show, in some measure, the truth or error of that gentleman's theory; either in the one case by a sensible diminution of the vertical movement of the tide, when compared with the known rise and fall on the shores of England and Holland, or in the other by ascertaining the rise and fall, beyond a doubt, to be so great as to throw some doubt on the correctness of the theory in question. But as I apprehend that Mr. Whewell's theory is founded mainly upon the fact, that the tide waves, to make high water on the opposite coasts of England and Holland, come from different directions, namely, on the former, round the northern extreme of Great Britain, and so working its way along the eastern coast; and on the latter, through the straits of Dover, and running thence along the coasts of France, Belgium and Holland; and that it might reasonably be inferred, that these waves gradually diminish in importance as they recede from their respective shores, or approach each other, there would be left a broadish space about the middle of this part of the North Sea, where no rise and fall of tide exists, and that therefore the waters between the two opposite shores would assume a convex form at low water by the shores, and a concave one at high water.

Allowing this view of the foundation of Mr. Whewell's theory to be correct, (and I have not his book at present near me to refer to,) this line, or more properly speaking, "broad belt" of no rise and fall, would doubtless run for a considerable distance in the north-easterly direction into the North Sea, from the point where it may commence on the North-Sea-side of the straits of Dover. It would therefore follow, that the fact of my being to the northward of Mr. Whewell's position would of itself be of no material importance, and by reference to the Chart, it will be seen that the longitude places me not many miles to the eastward of the "broad belt" above alluded to. Having thus reflected, I came to the conclusion, that if Mr. Whewell's views were correct, true observations made in this position would exhibit some indications thereof, and I accordingly made the necessary dispositions.

A rise and fall by the shore is a case which falls immediately on the conviction, by the sense of sight; but to ascertain the fact of a vertical motion of five or six feet in the middle of a great sea, and out of sight of land, is a problem of no small difficulty, and requires the exercise of many precautions to arrive at anything like true results. In making an observation of this description we find two important obstacles in the way of obtaining these, namely, the stream of tide and the undulating character of the surface of the ground. Under the influence of a strong stream of tide, it is utterly impossible, except in very shallow water, to take a strictly correct depth from the vessel, or a boat, at anchor, (and therefore a fixed point,) for the line *will* assume a curved form in the act of descent; and after all, from the want of perpendicularity in the line, a large allowance, in a depth of nearly twenty fathoms, is necessarily left to the exercise of the judgment; and both of these may amount to considerably more than the "rise and fall" sought for. On the other hand, the undulations of the surface render it essential that the depths should be always taken *over* some discovered elevated spot. The stream of tide and the undulations of the ground are therefore alternately opposed to the making of observations from which correct results can be derived. I experienced on this, as on the former occasion, considerable difficulty in overcoming these obstacles; but I soon found myself compelled to resort to the former plan, (with the addition of such precautions as experience then gave me,) namely, that of mooring one boat and taking the depths in another.

The accompanying diagram will assist my account of the plan pursued.



The ship was anchored in 21½ fathoms, and on searching, a convenient rise in the ground A was soon found near her, over which there was exactly 18 fathoms 3 feet, by a well-measured line. The second gig (of 26 feet) was then moored, "head and stern," in the direction of the strength of the stream (N.E. and S.W.), so that she should be as nearly as possible over the overfall A. This was accomplished thus:— I prepared a coil of 1½ inch rope, and fastened a grapnel at either end. The first grapnel was let go at B, the whole of the line was then veered away, and the second grapnel was let go at C; the gig was hauled along the bight of the rope, until it was found, by repeated trial, that the summit of the overfall was exactly abreast the foremast row-lock of figure D, at about six feet from the boat, while the N.E. stream was running. She was there secured. At the turn of the tide to the S.W., it was found that the weight of the stream F had operated so powerfully on the bight of the N.E. line, as to draw the boat from D to E, so that the summit of the overfall, which was before under the foremost row-lock, was found to be eight feet on her bow. On the return of the N.E. tide, its operation (G) upon the bight of the S.W. line again drew the gig ahead to her former position D, and the summit of the overfall was found as before under the foremost row-lock.

It will then be evident, that at each change of tide I knew exactly where the overfall was to be found, while taking the depths; and thus prepared, it only remained to get the *least* and *exact vertical* depth over the summit of the overfall at the intervals determined upon, and which were every half-hour. With the N.E. stream running, I dropped the lead from the other gig about the point H, and exactly in the stream, which I knew would drift her at the proper distance of six feet from the moored boat; the lead was constantly lifted off the ground, so that the line was perfectly straight and perpendicular, and the undulations of the ground carefully observed until the lead passed over the summit of the overfall, where the depths were strictly noticed, and recorded in the accompanying Table. The boat on this stream was allowed to drift to the point I. With the S.W. stream I began about

August 24th, 1840. Moon's Age, 26·6 days. Latitude 52° 27′ 30″ N. Longitude 3° 14′ 30″ E.

Times. P.M.	Depths.	Direct. (Comp.)	Rate.	Winds. (Comp.)	Force.	Remarks.
h. m.	fms. ft.		Kts. $\frac{1}{10}$s.			
1 0	18 3¼	N.E. ¼ E.	1 5	S.W.	2	
1 30	18 3	N.E.	1 4			
2 0	18 2¾	N.E. ½ N.	1 2			
2 30	18 2¾	N.E. ¾ N.	1 0			
3 0	18 2¾	N.E. by N.	0 7			
3 30	18 2	N.E.	0 5			
4 0	18 1	N.E. by E.	0 3			
4 30	18 1	East.	0 3			
5 0	18 1½	Slack.	0 0	S.S.W.		
5 30	18 2	W. by S.	0 3			
6 0	18 2½	S.W. by W.	0 7			
6 30	18 3	S.W. ½ W.	1 4	S. by W.		
7 0	18 3¼	....	1 5	South.		
7 30	18 3½	....	1 5	S.S.E.		
8 0	18 3½	....	1 6	S.E. by S.		
8 30	Too dark for observations.					
9 0						
9 30						
10 0						
10 30						
11 0						
11 30						
12 0						
12 30						
1 0						

August 25th, 1840. Moon's Age, 27·6 days. Latitude 52° 27′ 30″ N. Longitude 3° 14′ 30″ E.

Times. A.M.	Depths.	Direct. (Comp.)	Rate.	Winds. (Comp.)	Force.	Remarks.
h. m.	fms. ft.		Kts. $\frac{1}{10}$s.			
5 30	18 3	Slack.	0 0	Calm.	0	
6 0	18 3	S.W. by S.	0 5			
6 30	18 3	S.W.	0 7			
7 0	18 3	....	1 0	W. by N.	1	
7 30	18 3	....	1 3	....	2	
8 0	18 3	....	1 5			
8 30	18 3	....	1 3			
9 0	18 3	....	1 2			
9 30	18 3	....	0 9			
10 0	18 3	....	0 5			
10 30	18 3	S.W. by W.	0 2	....	......	Tide slack from 10·45 to 11·0.
11 0	18 3	Slack.	0 0	W. by S.		
11 30	18 3	N.E.	0 3			
12 Noon	18 4	....	0 9			
P.M. 30	18 4	....	1 3			
1 0	18 4	....	1 6			
1 30	18 4	....	1 6			
2 0	18 4	....	1 6			
2 30	18 4	....	1 6			
3 0	18 4	....	1 3			
3 30	18 4	....	1 0			
4 0	18 3½	....	0 5			
4 30	18 4	....	0 3	W.S.W.		
5 0	18 4	Slack.	0 0	S.W.		
5 30	18 4	S.W.	0 2			

(Signed) WILLIAM HEWETT, *Captain of H.M.S. Fairy*,
August 31st, 1840.

the point I and terminated at H, using the same observances and precautions until 5h. 30m. P.M. of the 25th, when the appearance of the weather required my removing.

It will be seen that the observations recorded on the afternoon of the 24th are not so regular as those of the following day. I attribute this to some degree of *uncertainty* on account of a long swell, perhaps of one and a half or two feet rise, interrupting the observation at the moment of passing over the overfall; but this little swell had nearly subsided on the 25th, and the depths were then recorded with much satisfaction. It will also be noticed, that at the turn of the stream about noon of the latter day, the depth had increased to eighteen fathoms four feet, and went on uniformly so; but I investigated the cause of this on the spot, and found that the wind having increased to 2 from W. by S., and therefore operating upon the starboard bow of the boat, had sidled her a few feet to the S.E., so as to bring the eighteen fathoms three feet immediately under her; and that by observing the same distance from the boat while drifting past her (and which was always on her larboard side), I obtained eighteen fathoms four feet instead of eighteen fathoms three feet.

From the care and pains taken in these observations, and *that* under favourable circumstances, I do not entertain a doubt of the correctness of any one of the depths over the summit of the overfall as recorded on the 25th; but as this interesting result of observations on an unexpected theory may no doubt give rise to a strong desire for further observations as corroboratives, I shall not fail to make such when I find myself in a position and circumstances to do so with any prospect of success. It is a difficult observation, and can be made but seldom. In the mean time I would offer my congratulations to Mr. Whewell on these results, should they prove in any degree gratifying to him. I have the honour to be, &c.

(Signed) WILLIAM HEWETT, *Captain*.

On a Machine for Calculating the Numerical Values of Definite Integrals. By the Rev. HENRY MOSELEY, *M.A., F.R.S., Professor of Natural Philosophy and Astronomy in King's College, London.*

It is the object of this machine to apply to the mechanical integration of an extensive class of functions, a principle suggested by M. Poncelet for the registration of dynamometrical admeasurements, and subsequently applied by M. Morin to an instrument called the Compteur, for registering the work or dynamical effect expended in the traction of loaded carriages upon common roads, and by a Committee of this Association (whose Report is contained in the present volume) to a permanent registration of the work of the steam upon the piston of a steam-engine. Professor Moseley stated his integrating machine to have some mechanical expedients in common with the last-mentioned machine, but to have nothing in common with the Compteur of M. Morin, except the fruitful and admirable principle of M. Poncelet.

It consists of a circular plate or disc placed in a horizontal position, and moveable about an axis passing through its centre. A wheel, which, from the function assigned to it, Professor Moseley calls the integrating wheel of his machine, is placed in a vertical position with its edges resting upon the superior surface of this plate, and with its axis (*i. e.* a line passing through its centre perpendicular to its plane) in a vertical plane passing through the centre of the plane. It is made to retain this vertical position, and at the same time to admit of a motion across the plate on which it rests, in the direction of a diameter, by the intervention of a guide composed of three parallel rods passing through three holes at corresponding points in the three arms of the integrating wheel and fixed at their extremities firmly into two discs, which discs are moveable about axes passing through their centres, these horizontal axes having their bearings in two pieces which admit of a vertical motion by means of keyed grooves in guides fixed vertically to the solid frame on which the plate rests; so that the whole weight of the frame and integrating wheel is borne by that point in the circumference of the latter by which it rests on the plate: the frame composed of the three parallel rods, and the discs into which they are fixed, is perfectly rigid, and is carried round by the revolutions of the integrating wheel; and the axes about which it turns being in a vertical plane passing through the centre of the plate, the frame serves as a guide along which that wheel may be made to traverse in the direction of a diameter of the plate, retaining always its position in a plane perpendicular to it.

One of the axes about which the frame turns is hollow, and through it a rod passes to the centre of the integrating wheel, through which it passes, being so attached to it (by means of a shoulder and nut) that the integrating wheel may turn freely on its extremity, whilst any motion communicated to it in the direction of its length may cause the wheel to move along the frame or its point of contact with the circular plate to traverse one of its diameters. This rod is fixed firmly at its other extremity to a short vertical piece, which connects it with another rod returning parallel to the first between it and the plate, and passing through an aperture in the same piece (sliding in vertical grooves) in which the hollow axis of the first-mentioned frame is fixed, until it nearly reaches the integrating wheel; its extremity is there turned downwards at a right angle until it just touches the surface of the plate. On the surface of the plate is elevated a curved edge or rail of a certain geometrical form, determined by the particular function which the machine is intended to integrate; and against the edge of this rail that small portion of the extremity of the last-mentioned rod which is turned downwards, is kept continually pressed by means of a spring acting against the vertical piece which forms the extremity of the frame composed of the two parallel bars, and which was last described.

The circular plate has teeth cut upon its edge, and is made to revolve horizontally by means of an endless screw fixed to the frame on which the plate rests, and thus revolving it carries round the integrating wheel by reason of the friction produced between its surface and the edge of that wheel by the weight which rests upon the latter, and is supported at their common point of contact; whilst the integrating wheel is thus made to revolve, its point of contact with the plate is made (at the same time) to traverse in the direction of a diameter to the plate, by the continued pressure of the edge of the curved rail on the extremity of the lower rod of the last described frame of two parallel rods; the whole of that frame, and therefore the upper of the two rods which compose it, being made by that pressure (the rail not being a circle concentric with the plate) to move in the direction of its length, and the integrating wheel to which the upper rod is attached being thereby made to slide along the first-described frame, which frame at the same time it carries round by the wheel.

Now it is evident that the point of contact of the integrating wheel with the plate being thus made to alter its position on a diameter of the latter continually by the pressure of the rail, as the plate to which it is affixed is made to revolve, the geometrical law of this change of position must be dependent upon the polar equation to the curve of the rail from the centre of the plate, or upon the relation of its radius vector (the centre of the plate being taken as the pole) to the angle which that line makes with any line given in position and drawn through the centre of the plate.

Now let it be conceived that such a geometrical form is given to the curved edge of the rail as to cause the distance of the point of contact of the wheel and plate from the centre of the latter to be a *given* function $f(\theta)$ of the angle θ described by the plate from any given position. The integrating wheel thus continually varying its distance from the centre of the plate, and its circumference continually revolving with the motion of that part of the surface of the plate with which it is in contact, it follows that the number of revolutions, and parts of a revolution, which are made by it, and therefore by the frame which it carries with it as the plate evolves from any given angular position θ_1 to any other θ_2, is represented by the definite integral

$$\int_{\theta_2}^{\theta_1} f(\theta)\, d\theta.$$

For the distance of the point of contact of the integrating wheel and plate from the centre of the latter being represented by $f(\theta)$, it is evident that, whilst the exceedingly small but finite increment $\Delta\theta$ of the angle θ is described by the plate about its centre, its point of contact with the wheel is made to describe an arc represented by $f(\theta) \,.\, \Delta\theta$; so that if in any position of the integrating wheel its distance from the centre of the plate be supposed to remain *unchanged* whilst the small angle $\Delta\theta$ is described by the plate, the circumference of that wheel will be made to describe a space represented by the same quantity $f(\theta).\,\Delta\theta$; and that the *sum* of all such spaces described on the same supposition, in respect to other positions of the integrating wheel or other values of the function $f(\theta)$ between the limits θ_1 and θ_2, will be represented by the sum

$$\sum_{\theta_2}^{\theta_1} f(\theta)\,.\,\Delta\theta.$$

If, therefore, the broken or interrupted variation here supposed to be given to the distance of the point of contact from the centre of the plate (and which may be conceived to be communicated by a jagged or step-like form of the edge of the rail) be replaced by the continuous variation actually communicated to it by the curve, this sum will pass into the definite integral*

$$\int_{\theta_2}^{\theta_1} f(\theta)\,.\,d\theta.$$

Now if N represent the number of revolutions and decimal parts of a revolution described by the frame or integrating wheel, and ϱ the radius of that wheel, the *sum* (or whole space described by the circumference of the wheel round its axis) is represented by the product $2\pi\varrho N$. So that

$$2\pi\varrho N = \int_{\theta_2}^{\theta_1} (f\theta)\,d\theta.$$

Let now a contrivance be applied to the instrument for registering the revolutions N of the frame, and therefore of the integrating wheel, to the 10,000th part, or to four places of decimals. This registration may be made by the common method of astronomical instruments; or more conveniently, and perhaps with sufficient accuracy, by means of a toothed wheel fixed on the axis of the frame, and running into a pinion in the proportion of 10 to 1: this pinion carrying a wheel which runs into a second pinion in the same proportion, and so on through a train of wheels and pinions, each *wheel* of which being divided into 10 equal parts, and numbered, will show one digit of the decimal part of a revolution up to as many places of decimals as there are *wheels*. The complete revolutions of the frame may in like manner be registered by means of a pinion on the axis of the frame running into a *wheel* in the proportion of 1 to 10. The value of N may thus be registered to four places of decimals.

Professor Moseley then proceeded to show—1st, that if the edge of the rail had the form of a straight line, or rather a curve, so slightly deviating from a straight line as to give to the point of contact the same motion as that point would receive from a straight line fixed upon the revolving plate, and actually passing through that point, and if the perpendicular distance a of this line from the centre were such that $\frac{a}{2\pi\varrho} = {}^{\cdot}43429$, and if the registration commence from that position of the plate in which the rail is perpendicular to the diameter traversed by its point of contact with the wheel, then will the number registered be represented by the formula

$$N = \log_{10}\left\{\tan\left(\frac{\pi}{4} + \frac{\theta}{2}\right)\right\}$$

So that when a straight rail is thus fixed upon the plate, the machine may be made to calculate the logarithmic tangent of any arc of the quadrant, and to replace a table of logarithmic tangents.

2nd. That if the edge of the rail were a circle whose circumference passed through the centre of the plate, and whose radius was equal to $\pi\varrho$, and if the angle θ were measured from that position in which the diameter of this circle coincided with the line traversed by the point of contact, then would the number registered be represented by the formula

$$N = \sin\theta.$$

So that with this form of rail the machine would serve to calculate mechanically the natural sines of angles, and to replace a table of such sines.

3rd. That if the edge of the rail were a curve slightly differing from an ellipse having its centre in c, and such that the point of contact of the plate and integrating wheel might be made to move precisely as it would if guided by the actual pressure of an elliptic edge, and e be taken to represent the ratio of the eccentricity of this ellipse to its axis major, and if its semi-axis minor be taken $= 2\pi\varrho$, then will the number registered be represented by the formula

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* See Poisson, Journal de l'Ecole Polytechnique, 18me cahier, p. 320; or Art. 2. in the Treatise on Definite Integrals, in the Encyclopædia Metropolitana, by Prof. Moseley.

$$N = \int_{\theta_2}^{\theta_1} \frac{d\theta}{\sqrt{1 - e^2 \sin^2 \theta}}.$$

So that the machine may be made with this rail to calculate an elliptic function of the first order of any amplitude θ whose modulus is e.

4th. That if the form of the rail were that of a logarithmic spiral whose pole coincided with the centre of the plate, and γ representing the constant angle of the spiral and a the radius vector from which θ was measured, if these quantities were so taken that $\frac{a \tan \gamma}{2\pi\varrho} = 1$ and $\varepsilon^{\cot \gamma} = 10$, then would the numbers registered be represented by the formula $N + 1 = 10^{\theta}$.

The arc θ is therefore the logarithm of the number $N + 1$ greater than that registered by unity; and if, connected with the endless screw which gives motion to the plate, there be a train of wheels registering the space described by a point in the plate at distance unity from its centre to four places of decimals, and beginning from that position of the plate in which the given radius vector a coincides with the diameter described by the point of contact of the plate and wheel, then when the register which gives the revolutions of the integrating wheel is made to show one less any given number N, that which gives the revolution of the plate will show a number which is the common logarithm of N; so that under this form the machine may be made to replace a table of common logarithms. The surface of the plate might in this particular case be advantageously replaced by the surface of a cone, and the spiral would then become identical with the *natural spiral* traced out by the convolution of a large class of turbinated shells*. The preceding examples of the calculations which may be performed by the machine are examples whose solutions lie within the ordinary resources of analysis, in respect to which the instrument could only serve to replace, perhaps conveniently, but (except it were constructed on a large scale) less accurately, well known processes of analytical calculation or tables already in use.

Professor Moseley next proceeded to show that there is a large class of functions whose analytical integration lies beyond the existing resources of mathematical science, the *mechanical integration* of which this machine would nevertheless effect. He then stated, that among the mechanical difficulties which would present themselves to the construction of such a machine were the following. Great accuracy would be required in giving their true geometrical forms to the curves fixed upon the revolving plate. It is unquestionable that a certain amount of error must always remain due to inaccuracies of workmanship in the forms of these curves; nevertheless to those who are acquainted with the wonderful education of the sense of touch and skill of hand acquired in the minute workmanship of some processes of the arts, (the engraving of type-founders' dies for instance, or the drawing of micrometrical lines on glass,) it will not appear impossible to reach, with the requisite care and patience, a very considerable degree of precision in this respect; and let it be remembered, that one type or model being thus attained, it may be reproduced infinitely, and with perfect accuracy, by casting in type-founders' metal, or perhaps by turning, or by the electrotype. Again, the difficulty of constructing these curves would, no doubt, in some degree be enhanced by the fact, that the guiding curve must be different from what it would be if the integrating wheel at its point of contact with the plate were allowed to be in contact with the face of the rail. This difficulty (not in itself considerable) may, however, wholly be removed. We have only to take the curves from the plate, and to place them on another circular plate parallel to and concentric with it, of precisely the same dimensions, but so far above it as to clear the integrating wheel; and then to give to the connecting piece of the two parallel rods a direction upwards instead of downwards, so that the second bar may pass to the superior surface of the upper plate; if this bar be then precisely of the length of the first, the point of contact will be made to describe a path on the lower plate precisely similar to the guiding point of the rail on the upper. There are, however, some important applications of the instrument, in which the curve admitting of an easy mechanical description, the guidance of a rail may be entirely dispensed with, the point of contact being made to vary its position according to the required law, by some more convenient or more accurate mechanical expedient; of this class are the ellipse and the logarithmic spiral.

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* This property of turbinated shells was published by Prof. Moseley in a paper on the Geometrical Forms of Turbinated and Discord Shells in the Phil. Trans. for 1838. It has since been confirmed by the admeasurements of Prof. Naumann, of Friburg, published in the Journal of Poggendorff for 1840.

On a New Calculating Machine. By Mr. Fowler.

The machine itself is on the principle of the old abacus, or calculating rods. At the first glance it has somewhat the appearance of a pianoforte, or organ, with all its keys laid bare. It would be impossible by mere description to make clear the details of the instrument, or the method of working it. The property of numbers on which Mr. Fowler bases the notation of his machine is, that any number whatever may be expressed by a proper combination of the powers of the number 3. The powers of 3 are in succession thus: the 0 power is 1; 1st, 3; 2nd, 9; 3rd, 27; 4th, 81; 5th, 243; &c. &c. Thus the number 14 may be expressed by subtracting from 27, or the 3rd power, the sum of 9, 3, and 1, the 2nd, 1st, and 0 powers, and similarly for all other numbers; the combination for some being more simple, for others more complicated. Instead of using the nine common characters with 0, nought, or zero, as in our common mode of numbering, Mr. Fowler only uses three marks, + when the power of 3 is to be added, — when it is to be subtracted; and the power itself is expressed by the place in which the mark stands: thus the number 14 would be + — — —, where the — most to the right means that the 0 power of zero, or 1, is to be subtracted; the next — to the left means, that the 1st power of 3 is also to be subtracted; the next, that the 2nd power of 3 is to be subtracted, and the + in the 4th place of figures means, that the 4th power of 3 is to be added. When any power belonging to any rank or place is not required in expressing any particular number, 0 occupies the place of either + or — in that place of the combination of characters for the number: thus + 0 — 0 — + would express 243 + 1, diminished by 3 and 27, or 214, to express which, the 3rd power of three, or 9, is not required; the 0 then in the third place expresses this, and yet gives the proper value to the —, 0, and +, in the 4th, 5th and 6th places. Arithmetical operations are performed by the aid of these simple marks with all the rapidity and security of the simplest algebraic processes, and pretty much in accordance with the well-known algebraic rules: thus to add 214 and 14 the process would be thus:

$$\begin{array}{rcrrrrrr}
214 & \text{or} & + & 0 & - & 0 & - & + \\
\underline{14} & \text{or} & & & + & - & - & - \\
\hline
\text{sum } 228 & \text{or} & + & 0 & - & + & + & 0
\end{array}$$

Here the + and — in the place of the 0 power of 3 destroy one another; if the two —'s in the next place had a third with them, they would go on as one — to the 3rd place; that — is then supposed to be introduced, but to balance it a + is also introduced and set down below: we then have two —'s in the third place, which similarly give + below, and one — goes on to the fourth place, where the + and — already existing balance one another, or mutually destroy the —; that which has been brought on appears below, and so do the 0 of the 5th place, and the + of the 6th, there being nothing to alter them. One other simple example must suffice: multiplication of 214 by 14 will stand thus:

$$\begin{array}{ccccccccc}
 & & & + & 0 & - & 0 & - & + \\
 & & & & & + & - & - & - \\
\hline
 & & & - & 0 & + & 0 & + & - \\
 & & - & 0 & + & 0 & + & - & \\
 & - & 0 & + & 0 & + & - & & \\
+ & 0 & - & 0 & - & + & & & \\
\hline
0 & + & + & 0 & + & 0 & 0 & 0 & -
\end{array}$$

or 2187 + 81 — 1 = 2996.

The translation of a given number into the ternary combination of signs suited to express it, requires the aid of voluminous tables, which may perhaps be simplified.

In the machine, the successive rods have the power of the number that would be expressed by a +, or —, or 0, in the place in which the brass nail appears. The range of the machine is greatly extended by the use of the lines parallel to the zero line, for thus 3 +'s or 4 —'s may be in succession placed by the rod being carried down 3 lines or up 3 lines, and thus additions and subtractions are performed by the very motions which work the rods in the processes of multiplication and division. The extent of power of the machine will be conceived if we consider that 7 +'s followed by 480 can be set on the machine, and would represent the number

87104955839944780770790212;

while 55 +'s would be, if all the rods were set one line only below the zero,

87224605504560089535585253, or

87 quadrillions, 224605 trillions, 504560 billions, 89535 millions, 585253 thousands.

Letter from Sir John F. W. Herschel, dated July 31, 1841.

Sir,—Allow me to request that you will submit to the inspection of the Physical Section of the British Association the annexed specimens (fifteen in number) of coloured Photographic copies of engravings and mezzotintos, into the preparation of which no metallic ingredient enters, the whole being tinted with substances of vegetable origin variously prepared.

The rays of the spectrum which have eaten away the lights in these Photographs, are neither the so-called chemical rays beyond the violet, nor the calorific rays beyond the red. The action is confined almost entirely *to the luminous rays*, and of these more especially to those rays of the spectrum *whose colour* is most contrasted with, or which enter most sparingly into, the composition of the ground tint; a circumstance which, considering the great command of colour which this new variety of the photographic art affords, holds out no slight hope of a solution of the problem of a photographic representation of natural objects in their proper colours.

Unwilling to occupy the time of the Section so near its conclusion, I pretermit for the present all details of manipulation, and remain,

Sir, yours very obediently,
J. F. W. Herschel.

On Daltonism. By Professor Elie Wartmann *of Lausanne.*

Of all the organs of sense with which man has been provided, none is more delicate than that of vision: it is subject also to a great number of affections, the study of which is important in the highest degree both to the physicist and to the physiologist. One of the most remarkable of these affections is an incomplete vision of colours, which has been called *Daltonism*, from the name of the illustrious philosopher of Manchester, who first described it in an exact manner.

As the various treatises and scientific collections contain merely scattered data on this peculiarity of vision, it appeared to me that it would be interesting to collect together all the authentic materials for its history which have hitherto been published, for the purpose of comparing them with the results of new observations, and of being enabled, finally, to assign a common origin to all the varieties of this disease of vision. I extract from a work of considerable extent the following conclusions, which appear to me to generalize the known facts on the subject, and to agree with others which still remain unpublished.

1. There are two distinct classes of *Daltonians*, viz. the *dichromatic*, who can only discern two colours, commonly black and white, and who appear to be endowed with a remarkable faculty of seeing in comparative darkness; and the *polychromatic*, composed of individuals who perceive at least three colours normally.

2. Daltonism is not always an hereditary affection, nor does it always date from the birth. It appears in certain infants born of parents who possess ordinary vision, and independently of the order of birth and of sex.

3. Deep colours appear black to many of these persons, unless they are illuminated by a bright light.

4. The number of colours perceived in the spectrum by polychromatic Daltonians

is not constant; some of them see three only, others four (among which blue and red may be specially mentioned). The extreme colours, red and violet, are frequently not distinct to them. This latter fact appears to me to be intimately connected with the question as to the number of primary colours (*couleurs elementaires*).

5. The degree of polish of the coloured surface exerts an influence on the appreciation of its colour.

6. Some Daltonians perceive both the brightness and the coloration of complementary tints which are invisible to us.

7. Two colours, which appear to our eyes to pass into each other by a succession of intermediate tints, appear to them [Daltonians] in contrast with one another.

8. Daltonians see exactly as we do the black rays [spaces] discovered in the spectrum by Frauenhöfer, at least in that portion of the spectrum which to them appears illuminated.

9. Those colours which we call complementary do not always appear such to them; and conversely, the tints which they designate as complementary to those which they perceive, are not such to our vision.

It is remarkable that the subject of Daltonism appears to have been studied by the English only; for, with the exception of the works of Dr. Jüncher and Prof. Seebeck, it is difficult to refer to any researches on this subject but those of Englishmen. I shall be happy if by this notice I shall have excited physiologists and physicians to make new observations on the subject, and I shall receive with acknowledgement any which may be communicated to me.

On the application of a Coating of Gold by the Electro-metallurgic process to the Steel Balance-springs of Chronometers. By E. J. DENT.

It is customary to "blue the balance-spring" in chronometers, and the blue oxygenated surface (or coating) greatly increases the elastic force of the spring; on its removal the balance-spring suffers a nearly corresponding loss. This rigid oxygenated coating, on its first formation by heat, increases the strength of the balance-spring more than the additional application of the gold on its surface; and while it may be considered as a first process of rust, the gold surface is a protection from the ill effects of damp and saline atmospheres, to which chronometers are subject on ship-board, and particularly in tropical climates. Mr. Dent first applied the gold to a chronometer balance-spring which had been previously rated; on its being replaced in the chronometer he found the rate of the chronometer to be losing 41 seconds in 24 hours, which was caused by the removal of the blue oxygenated surface, and the gold coating not increasing the elastic force so as to compensate for the loss. Mr. Dent in another paper communicated the result of his experiments on the glass balance-spring in chronometers, since his first communication made to the Association at Cambridge in 1833, with observations on its official rate, resulting from five years' trial by order of the Lords Commissioners of the Admiralty.

On the Preservation of Magnetic Needles and Bars from Oxidation by the Electrotype process. By Professor CHRISTIE.

The author stated that the preservation of the identity of magnetic needles and bars employed in determining the terrestrial magnetic intensity, whether statically or dynamically, both as regards their magnetism and their weight, is so evident, that it was quite unnecessary for him to dwell upon the subject; but he might mention, that even in the case of the ruder instruments employed—as ships' compasses, it had been considered by experienced naval officers that it would be advantageous if the needles were efficiently protected from oxidation. On learning that the electrotype process had been applied by Mr. Dent to the protection of the balance-springs of chronometers, by forming a coat of pure gold on their surface, it occurred to him that the same process was admirably adapted for protecting magnetic bars and needles from oxidation. He now presented to the Section two needles, which, after having been magnetized, were coated with gold by this process. He considered that the same process could be advantageously applied to the protection of the axes of dipping needles: this however was a question which could only be decided by careful experiment, as it was very possible that the coating of soft gold on the axis might so much increase the friction on the agate planes, as to render the application of the process in this part of the needle objectionable.

The needles presented are of clock spring, and were magnetized in the ordinary way, by double touch, previously to being subjected to the electro-metallic process. Their weights before they had received the coating of gold were 225·4 grains and 222·1 grains, and afterwards 227·8 grains and 223·8 respectively; so that the coating of gold on the one is 2·4 grains, and on the other 1·7 grain. Previously to the application of this process of gilding, it is quite necessary that the surface of the needle should be well polished, and perfectly clean. Professor Christie remarked, that in the specimens before the Section, which were first attempts, in consequence of defect in the polish, the process had failed in particular points. This arose from his desire that the original surface of these particular needles should not be much rubbed down; but the defect is one which with due care and attention may easily be avoided. These needles still retained a considerable degree of magnetism, but this was greatly increased on their being re-magnetized by means of two bar magnets, then on the table.

On the Use of the Sliding Rule, with an account of some New Lines proposed for it. *By* J. BATEMAN.

This communication, which was illustrated by a sliding-rule with a radius of eight feet, the largest size yet graduated, embraced notices of the *ordinary* lines on a sliding-rule; the application of these to *cask-gauging*, by the use of a *mean* diameter, calculated or obtained by peculiar graduations on the rule; the proposal of Dr. Young and others, to obtain the contents of casks by one setting of the rule, without the previous finding of a mean; the causes why these attempts have been unsuccessful; and a description of the line of *special gauge points*, lately invented by Mr. Woollgar of Lewes (which required a double setting of the rule). The author stated, that all that is wanted by the practical cask-gauger is the completion of Dr. Young's lines, applied to casks of a spheroidal form, *i. e.* a graduation for finding the contents of such casks at one setting of the rule.

On Determining Distances by the Telescope. *By* EDMUND BOWMAN.

Instead of a graduated scale in the common focus of the eye-glass and object-glass, and a fixed measure held at an unknown (but limited) distance, the author advocates the employment of a fixed interval in the common focus of the eye-glass and object-glass, and a graduated staff held at the point whose distance is required to be known. This method he fully developes and describes, and by a very simple process makes the requisite correction for the varying distances from the object-glass of images which are derived from unequal distances from the observer. The author is of opinion, that, with suitable instruments and with adequate attention, observations may be made which shall give the distances truly to the one-thousandth part.

On recent Discoveries in Voltaic Combination. *By Mr.* DE MOLEYNS.

On an Instrument for Drawing Circles in Perspective. *By Mr.* GRELLET.

Notice of certain Barometers invented by Mr. Bursill. *By* W. G. GUTCH.

(The instruments are patented.)

Communications which arrived after the meeting broke up, were forwarded by Sir David Brewster, "On Crystalline Reflexion;" by Dr. R. Deakin, "Registers of Meteorological Instruments at the Baths of Lucca, in the Summer of 1840;" by John Marshall, Esq., "Notice of the Fall of Rain in Low and High Ground near Hallsteads, in Cumberland."

CHEMISTRY.

Some Inquiries into the Causes of the increased Destructibility of Modern Copper Sheathing. By J. Prideaux, *F.G.S.*

On the 29th of May last year, the author had been requested by Mr. Owen, of H.M. Dockyard, to analyse some sheet copper from the sheathing of the Sanspareil, which was still in good condition after thirty years' wear. The sample gave about 0·25 per cent. of alloy, chiefly tin, zinc and iron (see Table I.). This contrasted with another sample, quickly worn out, and which had given no quantity of alloy sufficient to weigh. These instances coincided with two recorded analyses of Sir H. Davy and Mr. R. Phillips, the former having detected in a sample of very durable sheathing about 1·400th of tin; the latter having found one which had lasted hardly four years, the purest copper he had ever analysed; and further, with the reputed inferiority of the recently prepared sheathing of the Royal Navy, which must have been much purified by repeated fusions.

The inference was, that the presence of tin and zinc was favourable to the durability of the copper; not perhaps from any advantage in the alloy, but as a guarantee of the absence of suboxide, which melted copper was liable to dissolve in refining, but which could hardly be supposed to coexist with zinc and tin: and nothing could be more injurious to the durability of the copper than being thus penetrated with oxygen, which must facilitate the action of the sea water, mechanically as well as chemically.

To bring this inference to the test of direct comparison, four other samples were submitted to analysis.

1. From the Minden, worn 17 years, annual loss 0·45 per cent.
2. „ Plover, „ 5 „ „ 11 „
3. „ Linnet, rapidly destroyed, no sheet left sound enough to weigh.
4. New sheathing from the Portsmouth mills.

The following table gives the results:—

Table I.

		Plover.	Linnet.	New.	Sanspareil.	Minden.
Copper, worn		5 yrs.	......	......	30 yrs.	17 yrs.
Loss per cent. per annum		11	unknown	......	......	0·45
Specific gravity		8·95	8·97	9·02	9·01	9·04
		Percentage of other metals.				
Analyses.	Tin	0·1	0·07	......	0·08	0·07
	Zinc	0·21	0·15	0·17	0·097	0·14
	Iron	0·13	0·36*	0·16	0·07	0·26*
	Silver	0·09	0·06	0·13	0·01	0·14
	Lead	......	trace.	trace.	trace.	......
		perishable.			durable.	

It will be observed that two of these samples wore remarkably well, and the other two suffered rapidly; but that there is no such distinction in the proportions of tin and zinc as to confirm the previous inference, or indeed to explain the differences of durability from the composition of the metal.

The cause of waste, then, not appearing in the analyses, was sought in the physical qualities of the samples; but neither their comparative hardness, tenacity, grain in fracture, nor colour, presented more consistent relations to their wear. The specific gravity only coincided with the durability, the heaviest having worn the best. The difference is small; but from these and other considerations, Mr. Prideaux had been induced to recommend that sheathing copper should be finished by cold rolling, to increase the pressure, and harden the metal, the better to resist friction.

It was another question, how far the waste was due to any defects in the sheathing itself, or to external causes. To determine this, a slip from each sample, of equal surfaces (4 × 0·5 inch), were immersed each in a pint of sea-water, the five vessels being placed each side by side, so as to put them all in like conditions. Sea-water being electro-neutral, and acting slowly on copper, a little sal-ammoniac was added, to quicken the action without affecting the neutrality. The following table shows the effects.

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* These two quantities of iron were probably a little increased by dust from the fire in evaporation.

TABLE II.—*Loss in sea-water sharpened with sal-ammoniac.*

	Plover.	Linnet.	New.	Sanspareil.	Minden.
In three days ……	1·6	1·5	1·4	1·8	1·5
In five days ………	2·5	2·7	2·5	3·0	2·6
In twelve days …	4·6	5·2	5·1	5·7	5

Here the greatest waste was on the Sanspareil's copper, the most durable of all in actual wear; and the least that of the Plover, one of those which had suffered most rapidly. Placed under like circumstances, the ratio of waste is quite different from that in use; which should therefore be more or less due to *external conditions.* These may depend on the relations of the copper to the ship, or on the circumstances of her employment. The upper edge and parts most subject to the wash of the sea, and to air and froth, suffer most from friction, as well as chemical action. The lower part wears much less when in deep water; but when the vessel grounds at low water in black mud, this part suffers most, from the action of sulphuretted hydrogen. The nails by which it is fastened to the ship can hardly be without their influence. They are never made of pure copper; are very numerous, all in metallic contact with the sheets, their heads presenting also a large metallic surface to the salt water, so as to give great effect to slight electro-chemical differences. Such effects had been very apparent on the Jane, whose copper had been worn out in four years; round some of the nails the copper being sound for an inch or two, although worn ragged in other parts, whilst the converse effect was exhibited round other nails, as though some had acted protectively, others destructively. Some instances were exhibited upon the table.

All the nails he had tried, though alloyed with tin and other electro-positive metals, were electro-negative to copper whilst clean, though assuming the electro-positive relation to it when crusted with verdigris, and the copper clean.

To ascertain their operation in these respects, five slips of new copper from the same sheet, and of the same size as above (4 × 0·5 in.), marked O. I. II. III. X., were suspended equidistant, and at the same depth, in a vessel of sea-water from the West Indies. O. was unconnected; I. II. III. X. were each in metallic contact with a nail, driven tight into a hole punched in the copper, the nails being taken from four different samples. After twelve days they were taken out and reweighed, withdrawing the nails; the following are the results:

TABLE III.—*Electro-chemical effect of the nails.*

	O.	I.	II.	III.	X.
Loss in twelve days…	0·32	0·34	0·28	0·41	0·37

All the nails, except one (which was from H.M. Dockyard), seem to have acted destructively, No. 3. having been one of those which had exhibited the same indications on Mr. Moore's ship Jane, quoted above.

Here appears to be *one* instance of a protective nail; not enough so to prevent all waste of the copper, which experience has not shown to be desirable; but doubtless the preservative power may be increased to any requisite degree by attending to the composition of the alloy, as will be presently explained.

The waste due to the ships' employment may be owing,—1. to excess of work; 2. to stress of weather, including electrical discharges; 3. to the effects of climate; 4. to corrosive materials in the different waters.

As the sheathing suffers from friction as well as from chemical action, the more the ship is at sea the greater will be her waste by friction; the more also will she be subject to stress of weather, which will act in the same way, and to electrical discharges, which will excite chemical action.

The Plover and Linnet, being packets, were very likely to have suffered from these causes (see Table I.): and the Acorn, which had undergone much thunder and lightning on the African coast, had lost of her copper 16 per cent. in 2½ years.

Climate.—That the sheathing suffers most in hot climates, is only what might have been expected from the usual increase of chemical action with the temperature.

Corrosive waters.—Did this property of heat, and also its tendency to promote nic production and decomposition, render the tropical waters more corrosive?

The copper from the Plover and from the Jane, near the water-line, which was spotted with uniform punctures in the shape of a horse-shoe, with a trail running invariably in the direction of the wash, looked as if damaged by organic action. The specimens were shown on the table. This appearance did not descend below the reach of air or froth.

To examine the question of increased corrosive power in tropical waters, Mr. Owen undertook to obtain samples from the Gulf-stream and other points; as well as from Falmouth harbour, where the packets are moored. Meanwhile appeared Professor Daniell's announcement of the large quantities of sulphuretted hydrogen in the waters of the Guinea coast.

The samples were collected and ticketed with due care: four from the Gulf-stream, one including the weed; two from the Caribbean Sea off Barbadoes; one from Falmouth harbour. No. 4, with the weed, was nearly saturated with sulphuretted hydrogen, the others inodorous. Neither of them reddened blue litmus paper, but all slightly affected red litmus paper, No. 4. blueing it distinctly. None but No. 4. affected sugar of lead paper. In specific gravity they were nearly alike—the Gulf and Caribbean waters, 1028·3; the Falmouth and Plymouth waters, 1027·4. They all required nearly the same proportions of chloride of barium to precipitate the sulphuric acid (No. 4, of course, excepted), and of carbonate of soda to throw down the earths.

To try the action of these different waters, five copper slips of the dimensions above (4 × 0·5 inch), cut from the same sheet, were suspended in a pint each of the following samples of water:—1. Heart of the Gulf-stream. 2. The same, with the weed. 3. Caribbean Sea. 4. Falmouth harbour. 5. Plymouth harbour. After thirteen days they were taken out and reweighed, having been put in all bright, but cleaned, on taking out, only with a brush in soft water, as in the other experiments:—

	1.	2.	3.	4.	5.
Loss in thirteen days	1·81	0·26	0·4	0·46	0·31

Nos. 1. 3. 4 and 5. were placed in a hot-house window, to assimilate to a hot climate. No. 2. being too offensive for this place, was put just beneath an unceiled southern roof, where the heat and light were inferior to the others. But the very small comparative waste of metal in this instance seems to be due to a pellicle on the liquid, constantly renewing after being stirred down. It seems to indicate more destructive action from the air and salt water than from sulphuretted hydrogen. No. 1. came out clean and bright; the others with tarnished surfaces, except No. 2, which was blotchy and speckled.

These experiments require to be repeated. The Falmouth water presented no indications of being more corrosive than that of Plymouth; and the great difference of waste in these two cases may be due to some unobserved difference of conditions. The excessive action of the Gulf-stream water can hardly thus be explained; not only the quantity wasted, but the metallic cleanness of the surface, show a manifest distinction.

But to whatever extent the recently increased waste of sheathing may be charged upon the greater velocity, more constant employment, and greater consequent liabilities of weather and climate of our shipping, particularly of the commercial class, as well as to difference in the nails, there is reason to fear the fault is still to be sought, too often, in the copper itself. The Quarantine Cutter, generally at anchor in Catwater, was coppered in October 1832, and her copper is now in a very good state. Her last sheathing held good fourteen years. The Eddystone tender, which also moors in Catwater, was coppered in July 1838, and is now in much worse condition than the Quarantine, which has been on service six years longer. That the waste on the Eddystone tender is not owing to her work, appears from the fact that her water-line, which suffers the wash and friction, continues sound (from a cause to be presently explained); the damage going on below, where the copper peels off in blue flakes. That this is attributable, in great degree, to her occasionally grounding upon the black mud, which generates sulphuretted hydrogen and other corrosive matters, is very probable; the other never grounds, and does less work. Yet the difference is very great to be thus accounted for; the one being in good condition after nine years' wear, the other coming to patch at the end of three. On neither was there any mark of electro-chemical action by the nails. The Tartar frigate, again, had her copper almost destroyed in four years, though never out of Sheerness harbour; and in such a case, where enough attention was paid to the subject to have the *copper analysed*, it might be supposed that so extensive an action from the *nails* could hardly have passed unnoticed. The author hoped yet to obtain some of the copper from the Quarantine and Eddystone tenders, and other samples from consistent instances, which should fix the fault upon the copper itself. Comparative analysis may then discover methods both to manufacture and to distinguish the sheet-copper best suited for this important purpose. Meanwhile, as nails must be used, advantage may be taken of their electro-chemical protection, by making them slightly positive to copper. The addition of zinc for this purpose need not injure their flexibility nor enhance their price. They are now alloyed *chiefly* with tin; but the care of the manufacturer is to make them sufficiently hard and flexible, without much regard to the presence of other metals. If they were made just so much electro-positive as to protect the sheathing so far as is compatible with their own durability, they would seem to offer the simplest, most perfect, and most convenient mode of electro-chemical protection. The test by the galvanometer would be easily applied (after a little practice) in making up the metal, if it be important to continue the present system of their manufacture.

A different method of preservation came out in the course of these investigations, which has since been made the subject of some probably conflicting patents.

It was above noticed, that the upper part of the copper on the Eddystone tender, which bears the wash and friction of the waves, continues sound; whilst the bottom is fast wearing out. This exception, or rather subversion of the usual conditions, is owing to a coating of fish-oil, laid on when the copper was new, to keep it bright, and not extended over the parts out of sight. Such a permanent effect could never have been anticipated from an oil which is not drying; and strongly indicates the facility, as well as efficacy, of this mode of protection. A still more striking case presented itself in the vessel which supplied the observations on the apparent influence of the nails. During the examination of her copper, Mr. Moore called his attention to the complete preservative effect of some coal-tar, which had trickled over the copper from the wood-work above. This had crossed the sheets where most subject to the wash and friction; and whilst the naked metal had been quite worn away, the coal-tarred streaks remained entire; the surface of the copper, on melting off the tar, being as perfect as when fresh from the rolls. The specimen was shown on the table.

Hence coal-tar seems to be an efficient preservative; but then recurs the question which encumbers this subject—will it keep a clean surface, free from organic adhesions and earthy incrustations?—the solution of which can be obtained only from time and experiment.

To embrace the opportunity for both, the vessel was then sheathed with copper on one side and yellow metal on the other; and her fore-quarters to her midlength varnished with coal-tar, laid on hot upon the metal, also heated by fires of chips round the sides. She has now been twelve months at sea, and by the last account of her, the varnished as well as the metallic surfaces kept quite clean. In the present stage of this investigation, Mr. Prideaux had not found the difference between durable and perishable samples of sheathing explained by comparative analyses, nor by comparison of their physical qualities. In parallel conditions in the laboratory, they did not observe the same order of waste as at sea; hence external causes must have had a principal share in the difference, namely, friction, as well as chemical action, in sea-going ships;—sulphureous exhalations upon those which lie on the black mud;—increased temperature, and heavy electrical discharges, in tropical climates, both exciting chemical action;—corrosive contents of some sea-waters. The nails used for fastening it have also considerable electro-chemical influence.

But allowing for all these causes, there are cases where the fault appears to be in the copper itself. The electro-chemical influence of the nails may be easily rendered protective; and coal-tar seems to afford an effective mechanical protection. Laboratory experiments must however, in such cases, be taken chiefly as indications for others on the working scale, which require opportunity as well as time. By sending ships to sea, each having her two sides sheathed with different coppers, but fastened with the same nails, the shipwright would soon learn whose copper he can best confide in, and the chemist would be supplied with materials for satisfactory comparative analyses.

Mr. Prideaux exhibited a specimen of a compound of oxide of lead with empyreumatic oil, produced in the distillation of wood, and forwarded by Mr. A. Tunstall of Neath. This compound, which had some resemblance to diachylon, was entirely soluble in boiling water, from which sulphuric acid separated the lead, and the oil floated on the surface.

On the influence of the Ferrocyanate of Potash on the Iodide of Silver, producing a highly sensitive Photographic Preparation. By Mr. R. HUNT.

The author having been engaged in experiments on those varieties of photographic drawings which are formed by the action of the hydriodic salts on the darkened chloride of silver, and, with a view to the removal of the iodide formed by the process, from the paper, was led to observe some peculiar changes produced by the combined influences of light and the ferrocyanate of potash. It was found that the ordinary photographic paper, if allowed to darken in sunshine, and then slightly acted on by any hydriodic salt, and, when dry, washed with a solution of the ferrocyanate of potash, became extremely sensitive to light, changing from a light brown to a full black by a moment's exposure to sunshine. Following out this result, it was discovered that perfectly pure iodide of silver was acted on with even greater rapidity; and thus it became easy to form an exquisitely sensitive photographic paper.

The method recommended is the following:—highly-glazed letter-paper is washed over with a solution of one drachm of nitrate of silver to an ounce of distilled water; it is quickly dried, and a second time washed with the same solution. It is then, when dry, placed for a minute in a solution of two drachms of the hydriodate of potash in six ounces of water, placed on a smooth board, gently washed by allowing some water to flow over it, and dried in the dark at common temperatures. Paper thus prepared may be kept for any length of time, and is at any moment rendered far more sensivive than any known photographic preparation, excepting the calotype, which it quite equals, by simply washing it over with a solution formed of one drachm of the ferrocyanate of potash to an ounce of water.

These papers may be washed with the ferrocyanate, and dried in the dark; in this dry state they are absolutely insensible, but they may at any moment be rendered sensitive by merely washing them with a little cold water.

Paper thus prepared is rendered quite insensible by being washed over with the above hydriodic solution, and from the photograph thus fixed many copies may be taken.

The author then described the action of the spectrum on this preparation, and pointed out, that the greatest effect was produced by the least refrangible rays, but that all the rays, excepting the *extreme red*, acted with considerable energy. The impressed spectrum was in all cases distinctly coloured from end to end; and it was found that the colours of superposed media left a corresponding tint upon the paper, but unfortunately as the paper dried the colours faded. These results bring nearer the probability of being enabled to produce eventually photographic pictures in their native colours.

The spectra formed on these papers were all surrounded by a marked space, which was protected from the influence of the dispersed light, exhibiting another proof of the fact noticed before, by Sir John Herschel and the author, that a class of rays, having peculiar negative properties, emanated from the edges of the sun. Some spectra and numerous specimens of these drawings were exhibited.

On Manures considered as Stimulants to Vegetation. By Professor DAUBENY.

In this paper the author discussed the question as to the sense in which manures may be considered to act as stimulants to plants.

It is evident, that if the term *stimulus* be understood in an acceptation similar to that in which it is employed with reference to the animal economy, it ought to be confined to bodies which by their presence assist in promoting the secretion and assimilation of the nutritious substances present, and ought not to include such as themselves afford materials for secretion. Thus salt and other condiments do not themselves nourish the animal, but by their presence induce its secreting surfaces to assimilate more readily the juices brought into contact with them.

Now it becomes a fit subject for inquiry, whether manures operate in the former manner or in the latter, and likewise whether the fact, that certain of them act less beneficially at subsequent periods of their application than they did at the first, admits of being explained on the recognised principle, "that stimuli lose their full effect upon living matter when frequently repeated."

Dr. Daubeny adduced several facts, which led to the inference, that nitrates of soda and of potass operate favourably upon certain crops by communicating to them nitrogen, and that the reason why these salts sometimes have appeared to leave the land in a worse condition than it was in before their use, is not that they are stimuli, and therefore amenable to the law above quoted, but is because the free supply of nitrogen afforded by their decomposition had caused the plant to absorb a larger portion of those other ingredients, such as phosphate of lime, silicate of potass, &c., which are present only in a limited quantity in the soil, thus tending to exhaust the latter of these materials, and causing thereby an inferior crop to be produced in the following year.

Now though it may be true that the nitrates in this manner indirectly stimulate the vital energies of a plant, yet it was conceived that the term *stimulus* had better be abandoned with reference to such cases, as its adoption might lead to an erroneous impression in the mind of the farmer, with respect to the proper mode of restoring to the land its original fertility.

If the theory suggested by the author be the true one, it will follow, that the proper remedy would be, not to discontinue the use of the nitrates, but by the application of bone-manure, &c., at intermediate periods, to restore to the land those other ingredients which had been abstracted from it in too large a quantity.

To determine what materials are wanting, and in what proportions they ought to be applied (independently of the empirical plan of ascertaining by repeated trials the substances which by their addition succeed best in remedying the deficiency), two methods present themselves. The first, a difficult one, is to learn, by a minute analysis of the soil, whether the ingredients which the crop requires are actually present, and to add of these a quantity equal to that which the intended crop is calculated to contain. The second, a more practical scheme, is to estimate, in the first place, how much of these substances exists in the crop taken off the ground, and then to add to it at least an equivalent quantity in the shape of manure.

The Professor suggested, that a kind of book-keeping should be undertaken in farming establishments on this principle, a debtor and creditor account being made out, of the quantity of nitrogen, of earthy phosphates, of alkali, &c., abstracted in the form of crop, and restored in that of manure each year.

He then concluded the paper by specifying certain points relative to this subject, which seem to require further investigation:

1st. To confirm or disprove his theory with respect to the operation of the nitrates, by determining whether they actually diminish in quantity, and finally disappear, after several successive crops have been grown upon land impregnated with these salts.

2ndly. Whether the same explanation applies to the agency of common salt and other mineral manures as to that of the nitrates, or whether any of them act directly as stimuli.

3rdly. More extended and exact data relative to the amount of alkaline and earthy salts, as well as of nitrogen, present in the various crops cultivated by the farmer, as well as in the manures he employs.

On the Disintegration of the Dolomitic Rocks of the Tyrol. By Prof. DAUBENY.

The author attempted to explain, without resorting to volcanic agency, the abrupt form, extraordinary height, naked outline, and fissured surface of the dolomitic rocks in the Tyrol. He attributed the above circumstances to the slow rate at which decomposition proceeds in rocks consisting of pure dolomite, and to the strength of cohesion which binds together the particles of this rock, owing to which, even those portions which stand prominent, in consequence of the removal, by the agents of destruction, of their contiguous parts, often remain unaffected by the mechanical forces which would cause the projecting portions of a rock less unyielding in its texture to become detached. The cause therefore of the greater height which is maintained by the dolomites of the Tyrol than by the pyroxenic rocks which accompany them, seems to be the inferior rate at which decomposition has proceeded in the former, whilst the bold and jagged outline they display may have been produced by the tenacity with which their parts cohere. The sterile character of these same rocks, even in parts which are not precipitous, appears to be owing to the slowness with which they decompose, as well as perhaps to the absence of organic remains. The Professor concluded with some suggestions as to the means of fertilizing rocks containing magnesia, in cases where, from the slowness of their decomposition, they continue sterile; and proposed in such cases to accelerate their disintegration, by pouring upon the subsoil diluted sulphuric acid.

Practical Method of determining the Quantity of Real Indigo in the Indigos of Commerce. By Dr. SAMUEL L. DANA, *of Lowell, Massachusetts, U.S.*

Dr. Dana is chemist in the most extensive calico-printing works of the United States. Not less than 50,000 lbs. of indigo are consumed annually in that establishment. Hence the importance of guiding the purchasers of that article by the results of easily performed analyses of samples. The following is the method employed by Dr. Dana, and which he requested might be laid before the Chemical Section of the British Association:—

1. Reduce the indigo to an impalpable powder.

2. Boil, in a long-neck flask (a Florence flask will do), ten grains of indigo, a few minutes, in 2½ oz. of a solution of carbonate of soda, marking 30° to 35° on Twaddel's hydrometer; then add eight grains, in crystals, of muriate of tin, and boil for half an hour. A beautiful yellow solution of indigo will be obtained. Withdraw from the lamp, and,

3. Introduce into the solution (2.) 500 water-grain measures of a solution of fifty grains bichromate of potash in 4000 grains of water. The indigo blue, with a trace of indigo red, will be precipitated, while the other components remain in solution.

4. Filter the precipitate (3.) through a double weighed filter, washing the mass with one ounce of muriatic acid diluted with three ounces of boiling water; wash with hot water till only water returns.

5. Separate, dry and weigh the filters; note the weight of the precipitate; burn one filter against the other; weigh; the difference is the silica contained in the indigo, which, deducted from the weight of the precipitate, gives the quantity of pure indigo.

Dr. Dana states that he has verified the accuracy of this mode by repeated results obtained in the dye-house; the indigo spending exactly in proportion to the quantity of that substance as found by analysis. He has also been able to use much more productive indigos since the agent of his house in Calcutta has been instructed by the results of these experiments.

Mr. Walter Crum, who communicated the above, adds the remark:—Carbonate of soda with protoxide of tin does dissolve indigo and forms a yellow solution, but so slowly, that I doubt if all the ten grains are acted upon. I think Dr. Dana must mean soda-ash, which contains a notable quantity of caustic soda; but a much weaker solution of caustic soda would answer the purpose.

Some Experiments showing the possibility of Fire, from the use of Hot Water in warming Buildings, and of explosions in Steam-engine Boilers. By GOLDSWORTHY GURNEY.

After detailing several instances of fire which arose from the steam pipes of water apparatus used for warming houses, the author proceeds to describe some of the experiments likely to be of practical value. From a tubular boiler, driving a high-pressure engine, the injection pump was cut off; half an hour after the supply pump was stopped, no water appeared on opening the gauge cocks, and the engine was observed to slacken its rate and to move sluggishly; it had dropped from 50 to 30 strokes a minute. The steam pipe from the boiler to the engine was 40 feet long, and was carried for convenience through the open air, thickly wrapped round with woollen cloth to prevent radiation: soon after the engine became sluggish, the woollen cloth was observed to char near the boiler, an effect which soon extended along the whole length of pipe; the engine still working, but with more apparent difficulty, making only 16 strokes per minute; the pressure gauge, which usually ranged between 30 and 40 pounds, now stood at 15, and was gradually sinking. In about five minutes after the woollen cloth had charred, a lead flange, used as a packing at the cylinder joint, melted, and was followed by a loud escape of elastic matter. The engine stopped working, and on bringing a lighted match into the escapage, it took fire, and burnt with the lambent flame of hydrogen gas. The author's impression was, that the escaping vapour was not pure hydrogen. Water condensed on a piece of cold iron held in the flame, but no water condensed on the cold iron after the flame was extinguished. On examining the boiler, all the tubes were found red-hot. This experiment was repeated with many modifications. The temperature of the escaping vapour was ascertained by means of bars, previously prepared to melt at different temperatures; these indicated a temperature of about 400°. In about eight minutes a piece of pure lead melted—woollen cloth was charred, and a piece of tow held in the escapage took fire. In other experiments it was found that the pipes became sufficiently hot to explode gunpowder and many chemical preparations.

Having satisfied himself of this property of heated steam or elastic matter, formed from the last portions of water in a boiler, the author proceeded to examine, as far as possible, its chemical nature—to determine whether any decomposition, or new elementary formation, took place. He found that the elastic matter was not condensable over cold water, and would not in many cases burn, or show any indications of the presence of hydrogen, or other inflammable matters. In some experiments it was found to extinguish flame. The experiments with copper vessels afforded the same results as those manufactured from iron. From these experiments it appeared, that whenever the heating apparatus falls short of water, the elastic matter formed over the fire will carry sufficient heat through close pipes, to any distance, to set fire to wood and other combustible bodies, and that whether the hot-water apparatus be under pressure or not, or whether the heating surface be of tubes, plates, or cylinders. On the other hand, it would further appear, from some experiments enumerated, that in no case is there danger when a given quantity of water is present. Mr. Gurney suggests, that if both ends of the circulating series in hot-water apparatus, namely, the part which immediately goes from the heating surface beyond the furnace, and that part where the circulation returns to it before it enters the furnace, were made of a metal which would not melt at the fair working temperature of the water, but which would melt at a temperature of from 500 to 600° of heat (say lead pipe), there would be little, if any, danger from fire.

On Spontaneous Combustion. By A. BOOTH, *F.L.S.*

The author stated that he had nothing novel to offer either in the way of theory or facts, but simply to draw attention to a long series of circumstances in well recorded and authenticated instances. These were scattered throughout the various scientific and public records, and had never been collected into any form. From his inquiries he was satisfied that many fires originated from the phænomenon of spontaneous combustion, and he considered it highly proper that persons should be put upon their guard with respect to the operations of an insidious danger. He commenced by noticing pigeons' dung, which was known at a very remote date, as Galen observed that pigeons' dung takes fire when it becomes rotten, and that the dung of a pigeon was sufficient to set fire to a whole house. This is further confirmed by Father Casati, a Jesuit, who relates to have been informed, that from the great quantities of the dung of doves, large flights of which used for many ages to build under the roof of the great church of Pisa, sprung originally the fire which consumed the said church. Cases had been also recorded of dung-hills and stable litter, turf and peat, corn, wheat-flour, oatmeal, torrefied vegetable substances, as saw-dust, roasted coffee and chocolate nuts, beans, peas and lentiles, and charred or heated vegetable substances, malt and torrefied bran, the latter of which was much used in different parts of Germany as an external application for diseased cattle. He also adduced instances of madder, saffron, hay, charcoal, charcoal and coal ashes, lamp-black, coal, nitric acid packed in saw-dust, tan, vegetables boiled in oil or fat, wool, wool combings, woollen cloth, woollen stuffs, cotton, cotton goods, cotton prepared for dyeing, waste cotton in manufactories, candlewick yarn in imitation of cotton yarn, hemp and flax, oakum and linseed oil, hempen fibres and oil, drying oils, cere cloth or oiled canvass, sailcloth, rags, paper, paint, cloth used in wiping paint-brushes, &c. Mr. Booth said that his attention was strongly impressed upon these circumstances some years back, on account of the execution of a young man named James Butler, on suspicion of setting fire to a floor-cloth manufactory. He felt convinced that this unfortunate young man was an innocent victim of the law, and that spontaneous combustion was the cause. An instance recently occurred in London, in which two persons were apprehended and remanded at a police office on suspicion of setting fire to a manufactory of patent felt, which was afterwards found to be produced by spontaneous combustion. He considered the subject as of high importance in a social point of view, and particularly where large constructions were concerned, as in the case of the late fire on board the Talavera.

On some instances of Restrained Chemical Action. *By* E. A. PARNELL.

The object of this paper is to add to the list of circumstances which modify or prevent the action of chemical affinity, the presence of water in the sphere of decomposition producing a force of considerable power, and one whose action has not been hitherto recognised. Its existence has been traced by observing the want of action of certain gases, and especially sulphuretted hydrogen, when in a perfectly dry state, on substances on which they exert a vigorous action in the presence of water. Thus papers impregnated with salts of lead, mercury and copper, were preserved from the action of sulphuretted hydrogen if rendered absolutely dry. That the effect of water in permitting action between these same bodies, does not wholly depend on diminution of the force of cohesion, by dissolving either the gas or the salt, is proved by several circumstances. 1st, This want of action is perceived only on particular salts; 2nd, to restore the action, water may be present in a state of combination with the salt, and can then exert no solvent power; 3rd, on moistening different dry salts with absolute alcohol, which dissolves six times its volume of sulphuretted hydrogen, and exposing to the gas, still no action ensued.

On considering the nature of the salts on which the action of sulphuretted hydrogen is restrained, it appears that the function of water, in permitting action, is to combine with the acid, which should be rendered free by sulphuretted hydrogen immediately on its liberation. One equivalent of water is not in every case sufficient to satisfy the acid; for all anhydrous salts of the oxides of mercury, copper or lead, can produce one equivalent of water with sulphuretted hydrogen.

The action of water may in some measure be assimilated to that between sulphuric acid of different degrees of strength, and metallic iron or zinc. These metals, as is well known, undergo no change in oil of vitriol; while in this case, as well as when dry sulphate of lead is exposed to dry sulphuretted hydrogen, it would be said all is present that is necessary to produce decomposition. But in both cases water must be added for action to ensue; in the one, to unite with sulphate of zinc about to be formed, and in the other with the sulphuric acid. But there are some salts of those metals which are unacted on by sulphuretted hydrogen when dry, whose acid, or hydracid of its salt-radical, possesses but little affinity for water, and consequently to which this explanation will not apply. In considering the cause of the want of action here, it must be remembered that sulphur is in reality a weak radical; that, if the salt be soluble, a force is called into action, when its solution is acted on by sulphuretted hydrogen, which possesses great power over the results of chemical action, namely, insolubility of the sulphuret; and water being present, with which the acid can unite when free, it does not follow that decomposition must occur in one case, because it will in another under the influence of other forces. The author concludes by suggesting an explanation of the singular action between potash and carbonate of lime, in presence of a small quantity of water, observed by Prof. Liebig—carbonate of potash and caustic lime being formed. Both caustic potash and carbonate of potash have a strong affinity for water, but of the two, caustic potash the greater. Here is sufficient water to supply the demands of the carbonate, but not of caustic potash; the result is, carbonate of potash and caustic lime are formed.

On some subjects connected with the Sulphocyanides. *By* E. A. PARNELL.

The author referred to a paper published in the Phil. Mag. for October 1840, in which it was shown that the substance supposed to be the isolated radical of the sulphocyanides (obtained by the action of chlorine or nitric acid on sulphocyanide of potassium) contained hydrogen as an essential constituent, and could not therefore be regarded as that radical. The present communication consists, first, in an investigation of the evidence on which this body acquired its character as the radical; secondly, an examination of other reputed sources of this substance; thirdly, of the action of iodine on sulphocyanide of potassium; and lastly, some theoretical considerations on the constitution of the sulphocyanides. Three arguments may be advanced in favour of the radical character of the body procured from the sulphocyanides by chlorine; first, its analysis; second, the mode of its formation; and third, so far as the existence of hydrogen is concerned, the circumstance of its formation from dry sulphocyanide of potassium, an anhydrous salt, by dry chlorine.

The evidence afforded by its analysis was, that M. Liebig obtained the same amount of sulphur as should be contained in the pure radical, and that it contained carbon and nitrogen in the same proportion as cyanogen. But this is the case with other substances which may be derived from the sulphocyanides: hydrothiocyanic acid, metasulphocyanogen, and the true radical, contain very nearly the same amount of sulphur, and also carbon and nitrogen in the same proportion as cyanogen. And as, on the other hand, it has been found constantly to contain hydrogen, its analysis has not been sufficient to justify its being considered the radical. With regard to the mode of its formation, were this radical either a simple or a stable substance, the process might have been expected to produce it; but its liability to decomposition in the nascent state is so great, that this argument is of little weight. Sulphuric acid, cyanogen, and an ammoniacal salt exist among the products. As to the circumstance of its formation out of contact with hydrogen or oxygen, that is, by fused sulphocyanide of potassium and dry chlorine, the author has been assured that sulphocyanide of potassium, usually considered to be an anhydrous salt, retains, after solution, recrystallization and fusion, a certain amount of water in combination; so that should the product of the action of dry chlorine on fused sulphocyanide of potassium contain hydrogen, as does the product of action of chlorine on solution of sulphocyanide of potassium, the source of the hydrogen is quite obvious.

The yellow product of spontaneous decomposition of hydrosulphocyanic acid, and the yellow precipitate produced in solutions of the sulphocyanides by voltaic agency, are considered by some to be identical with the product of action of chlorine. On examination each was found to consist of hydrothiocyanic acid; that is, the acid produced from metasulphocyanogen by the action of alkalies. The action of iodine on solutions of the sulphocyanides is precisely analogous to that of chlorine. There are produced cyanogen, *sulphuric acid*, ammonia, and metasulphocyanogen. A remarkable circumstance connected with hydrothiocyanic acid and metasulphocyanogen (products of decomposition of sulphocyanogen) is, that each contains twelve equivalents of sulphur, which is the number representing, according to Prof. Graham, the salimolecular group of that element, as founded on its isomorphism in one state with bisulphate of potash. Sulphocyanide of potassium retains, after once dissolved, precisely one-sixth of an equivalent of water, so that the equivalent of this salt, and probably of sulphocyanogen itself, must be multiplied by six; one equivalent will then include twelve atoms of sulphur. Hydrosulphocyanic acid thus falling to be represented as $S_{12}\,Cy_6 + H_6$, a rational formula is at once suggested for metasulphocyanogen, that of a hydrated hydrosulphocyanic acid, in which four out of the six equivalents of hydrogen have been removed, or $S_{12}\,Cy_6,\ H_2 + H\,O$.

Should these views of the constitution of sulphocyanogen prove correct, it must be viewed as a hexabasic radical, in whose salts each atom of the base must always be of the same name.

On the direct Formation of Cyanogen from its Elements. *By* G. FOWNES.

After referring to the experiments of Desfosses, which went to show that gaseous nitrogen, brought into contact with charcoal at a high temperature, an alkali being present, is absorbed in notable quantity, and a corresponding amount of cyanide produced; and also to the process for manufacturing Prussian blue, by Lewis Thomson, in which nitrogen is derived from the atmosphere, the author proceeded to show that the existence of nitrogen, in a solid state, in many varieties of charcoal, and the possible presence of ammonia in the nitrogen gas employed, were sources of error against which it was necessary to guard.

The author uniformly found, that whenever wood-charcoal or coke are ignited in a close crucible with carbonate of potash at a moderate red heat, cyanide in abundance is always produced, which is never the case with pure charcoal, provided the temperature does not exceed redness. After some preliminary trials, the results of which were unequivocal, a mixture of fifty grains of pure sugar-charcoal, and fifty grains of carbonate of potash, obtained by gently igniting pure bicarbonate, was placed in a porcelain tube fixed across a furnace, and maintained at a full red heat, while pure nitrogen gas, very carefully prepared by acting on solution of ammonia by chlorine, was slowly passed over the mixture. At the further extremity of the porcelain tube, a small gas-delivering tube was arranged, dipping into a vessel of water. At the commencement, the quantity of gas emitted by the exit end of the arrangement greatly exceeded that passed into the tube: it had no odour, did not render lime-water turbid, and burned with a bright blue flame, generating carbonic acid. After some time the carbonic oxide diminished in quantity, until at length nitrogen alone escaped. The tube, when cold, being examined, was found to contain a black porous mass, which hissed and became very hot on the addition of water. A little of the filtered solution gave, by "Scheele's test," abundance of Prussian blue; another small portion, acidulated with nitric acid, gave a copious white precipitate with nitrate of silver; and the residue, distilled with dilute sulphuric acid (the addition of which scarcely occasioned effervescence), afforded about half an ounce of tolerably strong hydrocyanic acid. Arrangements were made for repeating the experiment, employing the nitrogen of the atmosphere in place of that artificially prepared, the result of which was, as before, a black mass rich in cyanide of potassium.

The amount of carbonate of potash converted into cyanide by direct absorption of nitrogen, appears to depend very much on the temperature employed. In two trials, at a full red heat, the quantity of carbonate converted amounted to 11·5 and 12·5 per cent. of that employed. When, however, the temperature was raised to whiteness, much above the melting point of copper, the production of cyanide appeared much greater.

When carbonate of soda was substituted for the potash-salt, cyanide was generated, but it seemed with much greater difficulty. The fact therefore appears to Mr. Fownes to be established, that free nitrogen can at a high temperature combine directly with carbon, provided some metal or similar body be present, whose cyanide is permanent under such circumstances.

Abstract of a Letter from Prof. LIEBIG *to Dr.* PLAYFAIR.

Some interesting results have been lately obtained in my laboratory. M. Schunk has obtained a white crystalline substance, in large quantity, from the lichens which are employed to prepare archil (*Lecanora tartarea,* &c.), by extraction with æther. It differs from erythrine and the compounds described by Dr. Kane, in its insolubility in water. With alkalies it behaves in a remarkable manner. It dissolves readily in alkaline solutions, and is capable of being again precipitated by acids, if the solution be recently made; but if kept standing for some hours, acids produce no precipitate: it has then been decomposed, and is converted to carbonic acid and *orceine.* If the substance be dissolved in baryta-water, and the clear solution boiled, a large precipitate of carbonate of barytes occurs, and the filtered solution gives, on evaporation, large crystals of *orceine.* From this circumstance a number of phænomena on the colour of lichens can be explained, which Dr. Kane has described in his work on that subject.

I have performed many experiments on the legumin in beans, and some other leguminous plants, and have arrived at the remarkable conclusion, that this body is identical with the casein in milk of animals. It has precisely the same composition, and contains the same salts—phosphate of potash, potash, magnesia, lime and iron—as the casein of milk.

Dr. Will and Dr. Varrentrapp have devised an excellent method for determining the amount of nitrogen in organic bodies: it is very exact and easily performed. The substance is mixed with a quantity of caustic potash and hydrate of soda, and heated in an ordinary combustion tube to redness. All the nitrogen in the substance escapes as pure ammonia, which is condensed in a small and neat apparatus containing dilute hydrochloric acid. This solution is mixed with chloride of platinum, evaporated to dryness in a water-bath, and the excess of chloride of platinum is washed from the ammonio-chloride by a mixture of æther and alcohol. From the metallic platinum which remains after the ammonio-chloride is heated to redness, the quantity of nitrogen is to be calculated.

We have repeated all the experiments of Dr. Brown on the production of silicon from paracyanogen, but we have not been able to confirm one of his results. What our experiments prove is, that paracyanogen is decomposed by a strong heat into nitrogen gas, and a residue of charcoal, which is exceedingly difficult of combustion.

New extemporaneous Process for the Production of Hydrocyanic Acid for Medical Use. By ROBERT D. THOMSON, *M.D.*

The importance of prussic acid as a remedial agent in spasmodic diseases, such as hysteria, chorea, &c., has induced the author to bestow much attention upon the production of this acid, so as to obtain it always of uniform strength. He has accordingly subjected to trial all the processes which have been recommended in this country for the formation of prussic acid, and not finding them in all respects satisfactory, proposes the following process as less liable to objection than any of the preceding. The first step consists in forming a pure cyanide of lead. This object may be effected in various ways, either by precipitating acetate of lead by hydrocyanic acid as prepared from the ferrocyanide of potassium and sulphuric acid, according to the process of the Edinburgh Pharmacopœia, in a stoppered bottle, or by distilling from the mixed materials into a Wolff's bottle, containing a solution of acetate of lead. In either case a definite compound of cyanogen and lead will be obtained, which is to be carefully washed and gently heated. Care should be taken that the water in which the acetate of lead is dissolved is perfectly pure. Distilled water will frequently precipitate acetate of lead, owing to the greater or less quantity of carbonate of ammonia contained in rain-water. It may be removed, as has been pointed out by Prof. Liebig, by adding to the water, previous to distillation, a few drops of sulphuric acid, or a few grains of alum.

The cyanide of lead having been properly washed and dried, the next step in the process consists in decomposing it by means of sulphuric acid. In order to obtain an acid of the strength of the *acidum hydrocyanicum dilutum* of the London Pharmacopœia, or containing about two per cent. of absolute acid, the following formula will be found convenient:—

Take 46·36 grains of cyanide of lead,
2 fluid drachms of dilute sulphuric acid (London Pharmacopœia),
6 fluid drachms of pure distilled water.

Introduce the cyanide of lead into a stoppered bottle; mix the acid and water in a glass vessel; allow the mixture to cool, and then pour it upon the cyanide of lead; close the stopper and agitate the fluid and salt together. After standing for some time, pour off the supernatant liquor from the precipitated sulphate of lead, and preserve it in a stoppered bottle.

This formula is founded upon the circumstance, that dilute sulphuric acid of the London Pharmacopœia contains, in each fluid drachm, about 9·5 grains of oil of vitriol (SO_3HO). Two drachms will therefore contain 19 grains of oil of vitriol. The quantity required for saturating 46·36 grains of cyanide of lead is only 17·4 grains; but the small excess is useful in preserving the acid.

The advantage of this process, it will be observed, consists in the employment of liquid measures in apportioning the fluids, and in using an acid for the liberation of the cyanogen, which, although added in excess, possess a preservative instead of a deteriorating influence. The author is quite persuaded, from his experience of the use of hydrocyanic acid in medicine, that in spasmodic diseases it is one of the most valuable agents we possess; but he is of opinion that the prescriber should watch its action, and repeat the dose until the desired effect is attained.

On the Composition of Crystallized Diabetic Sugar. By ROBERT D. THOMSON, *M.D.*

Having observed various statements in books respecting the crystallization of diabetic sugar, the author was anxious to test their accuracy by experiment. On the first favourable opportunity the test was applied. An Italian, who had been labouring under diabetes for some weeks, was the patient from whom the urine was obtained. Its specific gravity was 1035; 300 grains of the fluid yielded 25·9 grains of sugar. The urine, when evaporated, afforded a honey-like residue; but upon carefully evaporating a portion, and pouring off gradually the fluid part, rhomboidal colourless crystals were procured. These possessed a saline taste, and upon being analysed, yielded—

Volatile matter	8·04	80·4
Common salt	1·96	19·6
	10·00	100

They were, therefore, obviously the well-known compound of sugar and common salt. According to Peligot, this compound contains from six to seven per cent. of water; the above analysis would therefore give—

Sugar	73·4
Common salt	19·6
Water	7
	100·0

The crystals were not quite pure, which accounts for the deficiency of common salt compared with the results usually given.

The author has since been enabled to obtain very regular crystals, and to procure any quantity of saccharine crystals from diabetic urine, by adding a small portion of common salt during the evaporation of the urine. He found that very regular crystals obtained in the Glasgow laboratory, and which were supposed to be pure sugar, contained common salt; the urine from which it was procured possessing an extra quantity of common salt. He has also been informed by Mr. M'Gregor of Glasgow, that the crystals of saccharine matter obtained by him in his experiments, were found, on being tested, to contain common salt. The facility or difficulty of obtaining crystallized diabetic sugar would appear to depend on the quantity of common salt existing in the fluid from which the crystallization is made.

These observations would therefore seem to call in question the accuracy of the conclusion, that diabetic sugar is capable of crystallizing in a regular form, or of assuming a superior crystalline structure to that of grape sugar.

On the Radical of the Kakodyle Series. By Prof. Bunsen.

The method recommended as the easiest of procuring kakodyle in a pure state is the following:—Chloride of kakodyle, carefully freed from the oxide by treatment with strong muriatic acid, is allowed to stand some time over chloride of calcium and quick-lime to remove the water and all excess of acid. It is then introduced into a distillatory apparatus, carefully filled with carbonic acid, and containing some slips of clean sheet-zinc. Any of the metals which decompose water will answer, but zinc is best. It is probable that hydrogen or carbon would produce a similar decomposition with suitable modifications of the apparatus. The vessel is then hermetically sealed, and the mixture of zinc with the chloride is exposed in a water-bath to a temperature of 212° Fahr. for some hours. When the decomposition is complete, a white saline mass is formed, which melts into an oily liquid between 240° and 248° Fahr. While the apparatus is still hot, the point of the tube leading into the condenser is dipped below the surface of boiled distilled water; as the apparatus cools the water rises into it. The tube is hermetically sealed; the water dissolves chloride of zinc, leaving the excess of zinc and the *kakodyle*, which falls as an oily liquid to the bottom. This is rectified twice or three times in vessels filled with carbonic acid as before, the water being afterwards removed by chloride of calcium in the usual way. Thus obtained it is a colourless liquid, transparent, and of a high refractive power, in appearance and odour much resembling the oxide of kakodyle; it ignites instantly on being brought in contact with air, giving off water and carbonic and arsenious acids. If air be gradually admitted, thick white clouds are evolved, and oxide of kakodyle and kakodylic acid are formed. If the supply of oxygen be insufficient for complete combustion, *erythrarsin* is deposited, mixed with a black fœtid layer of arsenic. In chlorine kakodyle burns with a brighter flame, depositing charcoal. Digested with zinc and muriatic acid, erythrarsin and a variety of other products are generated. Similar results are obtained with protochloride of tin, phosphorous acid, and other powerful reducing agents. It boils at about 338° Fahr., and freezes at about 21° Fahr., forming large square prisms, gradually changing into a mass resembling ice in appearance. The density of its vapour by calculation is 7·281; experimentally it was found to be 7·101. By combustion with oxide of copper, two experiments yielded the following results:—

	1.	2.
Carbon	22·30	22·23
Hydrogen	5·48	5·33
Arsenic	71·29	71·00
Loss and oxygen	·93	1·44
	100·00	100·00

which numbers closely agree with the following theoretical numbers:—

4 Carbon	23·15
6 Hydrogen	5·67
2 Arsenic	71·18
	100·00

This approximation is as great as can be expected, where the exclusion of oxygen is so essential, and so difficult to be effected.

Kakodyle thus insulated can be combined *directly* to form all the various substances of which this series consists. By direct exposure to oxygen the oxide and acid are formed. Sulphur dissolves in kakodyle, forming a solution which possesses all the properties of the sulphuret; and the higher degree of sulphuration is obtained with equal facility by the addition of a larger portion of sulphur. This is a solid, soluble in æther, from which solution it may be obtained in beautiful crystals. An aqueous solution of chlorine added to the radical occasions the immediate production of the chloride of kakodyle, and most of the other compounds may be procured with nearly equal facility. If kakodyle be distilled with chloride of zinc, various products of different degrees of volatility are obtained, containing various proportions of arsenic; the most volatile being the least disposed to spontaneous inflammation in the air, and containing the smallest amount of arsenic. By heating the vapour of any of these products in a jar over quicksilver to a temperature not greatly exceeding the boiling point of that metal, it undergoes decomposition, metallic arsenic is deposited, and carburetted hydrogen is formed, without the smallest deposit of carbon. The gaseous mixture burns with a clear bright flame, depositing a minute film of arsenic, caused by traces of a volatile arsenical compound, which gives the gas the property of inflaming when passed up by bubbles into a jar containing chlorine. Mixed with oxygen and detonated, 1·5 vol. of gas requires 3·5 of oxygen for combustion, and 2·0 vols. of carbonic acid are formed. This shows it to contain 4 vols. of carbon vapour and 12 vols. of hydrogen, condensed into 6 vols. Fuming sulphuric acid absorbs one-third of the carburetted hydrogen, and the remaining gas, when detonated with oxygen, gives the same results as marsh gas. It is unaffected by chlorine in the dark, but in sunshine forms camphor-like crystals, exactly like those produced in similar circumstances from the marsh gas. Among the products of the decomposition of kakodyle is a remarkable substance termed by Bunsen *Erythrarsin*. At present it can only be obtained as a secondary product, and the following method yields it the purest:—About 100 grammes of oxide of kakodyle are treated with strong muriatic acid; chlorine of kakodyle is the principal product, but at the same time a flocculent brick-red precipitate occurs, which remains behind after the chloride has been distilled: during the boiling it collects into darker coloured masses. It is treated several times with absolute alcohol to remove the last traces of chlorine. Air must be carefully excluded during the whole process, and it must ultimately be dried *in vacuo*, as slow oxidation would otherwise occur, arsenious acid being formed. The 100 grammes of oxide of kakodyle affords only 0·5 gramme of erythrarsin. Thus obtained, erythrarsin forms an amorphous almost inodorous mass, of a colour between dark red and steel-blue, and is easily reduced to a brick-red powder. It is insoluble in alcohol, æther, water, and solution of potash. Fuming nitric acid decomposes it with production of light. In weaker acid it also dissolves with decomposition.

Heated alone in a tube, fumes smelling of oxide of kakodyle are evolved, and a sublimate of arsenious acid and metallic arsenic is produced. The results of the only analysis made correspond nearly with the formula $C_4 H_6 As_6 O_3$. The calculated numbers are—

Carbon	8·73
Hydrogen	2·14
Arsenic	80·56
Oxygen	8·57
	100·00

The experimental results are—

Carbon	8·53
Hydrogen	2·08
Arsenic	81·56
Oxygen	7·78
	100·00

From the discovery of kakodyle the theory of compound radicals has received a confirmation scarcely to be gainsaid; for not only has the radical itself been insulated, but the whole kakodyle series has been formed from it directly. Further, the specific gravity of the vapour of the substance obtained is exactly what it should be for the radical, supposing the laws of condensation, which hold for inorganic compounds, to be applicable also to organic bodies. From the decompositions effected by heat on this radical, it seems not improbable that kakodyle is an arseniuretted compound of a binary radical, consisting of $C_4 H_6$. Erythrarsin may be conjectured to be an oxide of a ternary radical, containing three times as much arsenic as kakodyle; but this idea does not at present rest on any strong evidence.

On the Production of Sulphuretted Hydrogen by the Action of Vegetable Matter on Solutions containing Sulphates. By E. LANKESTER, *M.D.*

Dr. Lankester stated that observation had enabled him to detect sulphuretted hydrogen in water, by the presence of some peculiar animalculæ which caused a red deposit: he found it in lakes and springs near Askerne, in the dropping-well at Knaresborough, and other places situated on or near the great tract of magnesian limestone in that district. He enumerated a series of experiments, instituted with a view of investigating the source of sulphuretted hydrogen, from which he came to the conclusion, that it arose from the decomposition of the sulphates in contact with vegetable matter. In allusion to Prof. Daniell's experiments on the waters from the African coast, the author stated, that Dr. Clem has recently detected sulphuretted hydrogen to a very considerable extent in the sea-waters of the British coast. Dr. Lankester is of opinion, that the elements for the production of sulphuretted hydrogen are as abundant around our own island as on the coasts of Africa, but it is not developed to so great an extent from the want of a high degree of heat. He did not think sulphuretted hydrogen and malaria identical.

An Inquiry into the Nature and Properties of the new Element, or product of Electrical Action mentioned by Schönbein. By FREDERICK DE MOLEYNS, *M.A., F.G.S., F.L.S.*

The author stated, that the announcement made by Professor Schönbein of Basle, respecting the production of a new element by the action of electricity, which he called Ozone, early attracted his attention, in consequence of the author having, in the course of his electrical researches, been struck by the singularity of the peculiar odour which the power of the batteries he employed produced, to such a degree as to determine him, if possible, to solve the mystery.

In the Report alluded to, which was read at the Glasgow Meeting, Professor Schönbein stated that the disengagement of the odorous substance depended,—1st, upon the nature of the positive electrode; 2nd, upon the chemical constitution of the electrolytic fluid; and 3rd, upon the temperature of that fluid. He added, that his experiments went to show that well-cleaned gold and platina were *alone* capable of disengaging the odoriferous principle, and that the more easily oxidable metals, as well as charcoal, did not possess that property at all.

The results of the author's investigations fully proved—1st, that the disengagement of the peculiar odour was *not* confined to the less easily oxidable metals; 2nd, that by certain arrangements *all* metals, when acting as positive electrodes, may be made to develope the odoriferous principle; 3rd, that certain positive metals, when *not acting* as electrodes, will evolve this principle; 4th, that charcoal forms no exception to this rule; 5th, that all substances, whether crystalline in structure or otherwise, possessing the property of appearing luminous by friction, or of yielding sparks when struck, likewise possess the property of discharging, under such circumstances, the "peculiar odour;" 6th, *that iron and nickel develope this principle much more strongly than any other metal*.

The author conceived that Schönbein's error, in stating that gold and platina *alone* developed the odour, arose from the fact of his applying but one mode of evolving the principle, namely, by using the substances on which he experimented as positive electrodes in electrolytic fluids; it was therefore clear that if, as he stated, gold and platina only produced the odour when clean, it must have been next to an impossibility for the Professor to have evolved it from metals with surfaces more easily oxidable, and therefore in a condition to *conceal* rather than *develope* so subtile an element. There was no doubt of its evolution from all the metals employed by the Professor; but it was clear that, immediately on its disengagement, combination ensued with the particles of the film which enveloped the *ill-cleaned* surfaces of the inferior metals, and thus that all evidence of its existence vanished.

The author, considering the possibility of such an obstruction to the disengagement of the odour, contrived an apparatus, by means of which he applied friction to the surfaces of the positive electrodes, and in every case found that the odour was evolved more or less strongly. Schönbein's opinion, that ozone was the electro-negative element of an electrolytic compound, existing not only in aqueous fluids, but also in the atmosphere, made it a point of much importance to ascertain whether it could be produced in dry air or *in vacuo*. The author stated that he devised various expedients for the purpose of determining that interesting question. Having observed the odour to be produced with great intensity at the points where contact was made and broken in an electro-magnetic engine, when connected with the battery, the author constructed an apparatus by which magnets were made to revolve within a glass cylinder, in such a manner that the points of contact, and the pivots whereon the axis turned, were all within it. The cylinder could be exhausted at pleasure, or filled with dry air or gases; and effectual means were adopted for preventing leakage. He thus obtained a vacuum, and operated also in dry air, collecting the matters evolved over distilled water; and by such modes he clearly proved that ozone *could not only be produced in a dry atmosphere*, but *also in a vacuum, mercurial, and common*. In several instances, where distilled water had been admitted into an exhausted tube connected with the glass cylinder containing the odour, there was a much larger proportion of the tube unoccupied by the water, than calculation gave as the maximum space for the residual air after exhaustion, thus proving that ozone had been concentrated, or reduced to a substantial condition. On opening the tubes the odour was extremely strong, and quickly diffused, causing the same sulphurous smell as that prevailing in a place struck by lightning.

These experiments, varied and frequently repeated with similar results, led the author to the conclusion that the ozone of Schönbein, which he proposed, for reasons which formed the subject of a future paper, to name Electrogen, must be admitted into the list of supposed elements; that it was *not*, as developed by Schönbein and himself, an *anion* of an electrolytic compound, whose *cation* was *unknown*; and that probably it existed in combination in various forms of matter, which at present are considered, but which in reality are *not*, elementary.

The author added that he was still prosecuting those experiments, and hoped shortly to be able to add considerably to the proofs already adduced as to the elementary condition of ozone, and its chemical properties.

Mr. Tweedy mentioned, that about six months ago, a specimen was shown to him by a respectable mineral dealer at Truro, of what he called molybdic silver. however, it was of a very fusible character—melting before the blow-pipe readily, the flame of a candle—Mr. Tweedy conceived that bismuth must enter largely composition, and sent a small specimen to Mr. Prideaux for examination, who ascertained that it was nearly pure bismuth, he believed native. Some further specimens satisfied Mr. Tweedy of its being natural, and not artificial, and of its great value. It was found in a mine near Truro, in a large unproductive sparry lode, and only in one spot.

GEOLOGY AND PHYSICAL GEOGRAPHY.

On the Upper Silurian Rocks of Denbighshire. By J. E. Bowman, *F.L.S., F.G.S.*

The author commenced by referring to a paper 'On the Upper Silurian Rocks of the Vale of Llangollen,' read by him at the Glasgow Meeting (See Report for 1840, p. 100), and by stating that a partial re-examination of this district, and a survey of that large portion of Denbighshire which lies between the vale of Clwyd and the river Conway, during the present summer, have afforded him additional proofs of the soundness of the arrangement he then proposed, and shown that it is applicable to the whole of Denbighshire, notwithstanding some further new appearances still more difficult to reconcile with the typical series of Mr. Murchison. The lofty hills on both sides the great valley of the Dee as high up as Corwen, and all the county of Denbigh west of the vale of Clwyd, except the hills of carboniferous limestone which accompany the upper beds, consist altogether of upper Silurian rocks. On account of the absence of the Aymestry and Wenlock limestones, the changes of structure, and the alterations produced by cleavage, Mr. Murchison's subdivisions could not be adhered to. The author therefore proposes to arrange the Denbighshire series in the following descending order:—

	feet.
Upper Division.—1, 2, 3. Green and red sandstones and marly conglomerates, with fossils of the Ludlow rocks	100
4, 5. Blue argillaceous schists, variously affected by cleavage, rarely containing fossils of the Ludlow rocks	1000
Lower Division.—1. Thin beds of hardened schist without cleavage or fossils...	600
2. Parallel beds of blue or grey argillaceous shales alternating with others of lighter colour, giving a streaked or banded character to the section. Unfossiliferous; horizontal	1500
3. Coarse slates and flags with large Orthocera, &c. Cleavage nearly coincident with the bedding; often wanting. Lowest beds green, lying upon the lower Silurian rocks	1600
Total thickness of the Denbighshire upper Silurians	4800

Upper Division.—1, 2, 3. These beds are interesting, as containing, under the garb of the old red sandstone, the fossils of the upper Ludlow rock; and the more so, since the old red sandstone itself is entirely wanting in North Wales, its nearest point to the beds in question being the outliers of Clun Forest, at the distance of upwards of 60 miles.

4 and 5. These beds are the true equivalents of the upper Ludlow rocks, and generally do not differ much in appearance from the Shropshire type. Though for the most part very barren of fossils, *Terebratula navicula*, &c. have been found in a few localities. They are often affected by strong cleavage, resembling some lower Silurians; and however long exposed, usually retain their hardness and colour. A striking proof of their durability occurs in the bed of the Dee under Llangollen Bridge, whose piers rest upon the native rock in the stream. This bridge was built in 1346, yet after the lapse of five centuries the bed of the river is not now more than a foot below what was then its ordinary level. Beds of this age form a broad belt to the south and west of the carboniferous limestone range, and cap many hills of the lower division, north and west of the river Elwy.

Lower Division.—1. These thin and apparently siliceous schists occupy the beds of the Dee and the surrounding hills above Llangollen, and insensibly graduate downwards into the next, or middle portion.

2. These parallel argillaceous shales are of great thickness and extent, and may always be recognised by their streaked or banded appearance, nearly horizontal position, rare occurrence of cleavage, and total absence of fossils. Where the beds separate freely they form good building-stones. This section is extensively developed in the

hills on the south bank of the Dee between Llangollen and Corwen, and in a large portion of Denbighshire west of the vale of Clwyd.

3. *Slates and flags.*—This is by far the most important and valuable portion of the North Wales Silurians, since it contains numerous quarries that are extensively worked in the hills north and south of the vale of Llangollen, and in the district between the rivers Clwyd and Conway. They are not however so durable as the true Carnarvonshire or Cambrian slates, becoming brown and rotten on long exposure, like the "mudstones" of Shropshire, of which they are proved to be the equivalents, both by their place in the general section, and by the large Orthocera and Cardiolæ found upon the surface of some of the flags. The lowest beds rest upon true fossiliferous lower Silurian rocks.

In the chain of hills north of the great Holyhead road between Cerrig-y-Druidion and Pentre Voilas, rocks of this section assume a new and very peculiar character. They consist of numerous streaked beds of soft ferruginous schist, which soon crumbles down into small fragments, and of intermediate beds of hard amorphous greywacke, ten or twelve feet thick and several hundred feet apart in the upper part of the series, forming the summits of the hills, and gradually diminishing in thickness downwards. Collectively they cannot be less than 1200 or 1400 feet thick. As they occur on the confines of two great centres of volcanic eruption to the south and west, and as the beds along their whole line are everywhere thrown off from one or other of these centres, the author supposes that the greywacke beds have been formed by the mixture of volcanic ashes with the sedimentary deposits; and that after consolidation the schists have been altered by long contact with heated matter, which in its struggles to escape has first upheaved, and then burst through the surface; those portions which covered the immediate seat of the eruption having been altogether swept away, and the hills in question forcibly tilted aside. This altered character gradually disappears to the eastward of Cerrig-y-Druidion. All the lower division of the Denbighshire upper Silurians is remarkable for the singular uniformity, parallelism, and streaked appearance of the beds; for their freedom from twists and curvatures, and from cleavage; for their low angles of inclination, and for the general absence of organic remains. Their total thickness is estimated at 3700 feet, and their parallelism and freedom from contortion through so great a depth is attributed to the cessation of subterranean disturbances through a long continued epoch; a fact that would scarcely have been suspected at so low a point in the scale of the sedimentary deposits. The streaked character is supposed to be due to a slight admixture of felspar in some of the beds, which on weathering acquires a paler hue, and which may have been derived from some distant vent and diffused through the waters. Only one instance was met with of the beds being thrown up into high angles. This was in the rugged district between Llangollen and the head of the vale of Clwyd, near the north-east end of the Berwyn range, and exactly in the common line of strike of that and of two other independent mountain chains. Here they converge as to a focus, and appear to have been upheaved by so many distinct masses of pent up elements in their struggles to escape, which, meeting in a common centre, have by their combined forces effected this tremendous convulsion. The rocks are thrown into inconceivable disorder, the beds dipping at all angles; along the whole extent of one mountain 1200 feet high and above half a mile long, they are absolutely perpendicular, and seem to have been rifted and tossed on end in one entire mass. It is in the midst of this scene of devastation that the Dee "winds her wizard stream" through the vale of Llangollen; but the harsher features are worn down and concealed under the green slopes and hanging woods which compose the rich scenery of this celebrated spot. The author then compared the Denbighshire upper Silurians with their soft equivalents, the "mudstones" of Montgomeryshire; and showed their connection by instances of rocks of similar age, but of an intermediate character, from other localities. The chief difference is in the lower division. The same species of fossils occur in the contemporaneous beds of each portion in both districts, and in the same geological sequence, but very sparingly in Denbighshire; also the same general parallelism and low angle of dip; the same character of the jointed structure; and the same tendency to concretions both in beds and in detached ballstones.

The paper concluded by showing, from the altered appearance of the upper Silurian group in North Wales compared with those of Shropshire, the still greater differences that may be expected to occur in distant countries; that little or no stress can therefore be laid on mere lithological structure; but that as beds of the same age in widely separated regions are found to contain some fossils that have a common type and are identical in species, the study of organic remains should be considered as of paramount importance by the practical geologist.

On the Post-Tertiary Formations of Cornwall and Devon. By Mr. BARTLETT.

Mr. Bartlett detailed the circumstances under which these formations are found in Devon and Cornwall, consisting of raised beaches, drifted deposits in caverns, and fissures in lime rocks, and of submarine forests. Mr. Bartlett mentioned, in addition to the caves hitherto described, one named Ash Hole, in Berryhead; it was thirty yards long and six broad, and on the materials filling the cave lay four feet of loam and earth, containing land-shells of the genera *Helix* and *Cyclostoma*; also marine shells, such as the *Mytilus* of the coast, bones of the domestic fowl, and human bones, mixed with pottery and various implements; below these were found abundant remains of the elephant, and the usual cavern debris. In the lacustrine deposits he mentioned, as of usual occurrence, the remains of oak, ash, elm, willow, maple, &c. and of ferns and *Zostera*. These he considered as belonging to a later epoch than the cavern animals, which could hardly have existed at the same time with vegetation resembling that of the present day. He then described some of the usual characters of the raised beaches, which vary in elevation from twenty-five to thirty-five feet above sea-level, and consist of terraces of fine yellow siliceous sand, containing pebbles of chert, limestone, old red sandstone, greenstone, hæmatitic iron ore, &c.; together with abundance of shells,—*Purpura lapillus, Patella, Turbo, Nassa, Ostrea,* &c. with remains of *Echinodermata, Sepiadæ,* and rarely of *Gorgoniæ*. These phænomena, indicating changes in the relative level of land and sea, the author attributed to galvanic action exerting itself along peculiar lines of geographical range, such as the bottom of the British Channel, which had always been oscillating, from the earliest tertiary era.

An Account of the Fossil Organic Remains of the South-east Coast of Cornwall, and of Bodmin and Menheniott. By C. W. PEACH.

The line of coast examined commences at Veryan, four miles south of Tregony, and extends eastward by Gorran, the Blackhead, and Fowey, to East Looe. The cliffs are composed throughout of quartzose and slaty rocks, hitherto supposed by Mr. Conybeare and others, who have referred to them in their writings, to be destitute of fossils. But along the whole line Mr. Peach has detected traces of Brachiopodous shells and corals, and the stems of Encrinites are of frequent occurrence. From Veryan to Gorran the quartzose rocks rarely contain traces of shells, but in the calcareous slates in contact with dykes of greenstones at Blackhead, remains of corals resembling *Turbinolopsis*, and of the genera *Cyathocrinus, Spirifera* and *Orthoceras*, occur. Eastward, at Pridmouth, a fine specimen of the Platycrinite was found, with the column, pelvis, arms, &c. In the slate quarries of Fowey, remains supposed to be those of fish, and corals of the genus *Favosites*, were detected. Near Polruan encrinital stems nearly a foot long occur, together with remains of Trilobites, corals of the genera *Cyathophyllum* and *Favosites, Spirifera, Orthoceras,* and a fossil with structure resembling that of the *Sepiadæ*. At Pentlooe an equal-valved bivalve, resembling *Nucula*, and a species of *Orthis*, have been found; and at East Looe another fine specimen of an Encrinite, with column, arms, and tentacula attached; also specimens of *Cyathocrinus, Fenestella, Turbinolopsis,* and *Orthis*. At Bodmin the author had detected Encrinites in the slate quarries, and in those of Menheniott in Liskeard, the eye of a Trilobite in good preservation. On the beach below the cliffs at Port Mellin, near Mevagissey, the author observed traces of a lacustrine deposit, containing roots and branches of trees, and the elytra of beetles, exposed after a heavy gale.

On the Stratified and Unstratified Volcanic Products in the neighbourhood of Plymouth. By the Rev. D. WILLIAMS, *F.G.S.*

Mr. Williams stated, that the prevalent association over the different regions of the earth, of granite, gneiss, greenstones, porphyries, mica-, talc-, chlorite-, and clay-slate, had for some time past induced him to suspect that such common assemblage was not without its signification: recent observations in Devon and Cornwall had convinced him, that there existed an intelligible relationship in the community of their origin, viz. that they were all volcanic products. He would instance, first, the granite veins in the bed of the Erme river, above Ivy Bridge, of which he exhibited a horizontal section. He at first regarded them as veins which had been injected into the yielding joints and fissures of the fine jaspery grit rock; closer inspection showed him also certain very delicate threads of the same flesh-coloured granite, emanating from the larger joints, but ranging after the planes of deposition of the grit; and the jasper rock was no more dislocated there than elsewhere. Higher up the river-bed he came to what appeared a hard junction between the grit and the granite; the former was in a highly metamorphic condition, but its upper surface showed frequently that its laminæ of deposition had not been obliterated. Specimens of the altered rock, obtained from the immediate confines of the hard junction line, showed no mineral transition between the granite and the altered grit. He had observed below, that while the grit showed no evidence whatever of having been acted on by any unusual violence, most of the granite veins ranged in the direction of its normal joints. Almost the first specimen he obtained from one of these joints (upwards of four feet above the granite in mass) showed its walls to be perfectly granitified, the granitic matter shading out laterally in the most delicate pencillings, while nearly all the other joints afforded the same evidences of conversion, in a greater or less degree. From these facts Mr. Williams felt constrained to deny that the granite had ever been forcibly injected, and to infer that the entire phænomena might be better explained by tranquil fusion and conversion. He contended that the pre-existing sedimentary rock had been reduced and converted into granite by intense heat from within, traversing the joint-lines in their several directions, and radiating from them laterally among the laminæ of deposition, apparently indicating, that wherever the temperature amounted to its point of fusion, there the rock would be reduced to the same condition with the incandescent mass below. With regard to the elvans or greenstones, and the so-called clay-slate or killas, he considered that abundant evidence existed in Devon and Cornwall to show that they also were volcanic products, the former in their usual amorphous type, the latter in a stratified condition. On the shore of the Padstow estuary, west of Wadebridge, fourteen of these elvans might be observed at varying intervals, each one underlaid and overlaid by volcanic breccia, grit, ash and clay-slate: these greenstones all observed the same angle of dip, and precisely the same strike as the killas above and below them; indeed several of them are disclosed on the opposite side of the river, in the precise places which the direction of strike would have indicated, and there also tilted up at the same angle with the clay-slates above and below. This line of low cliff extends about a mile, the slates and elvans having a permanent southern dip, with one undulating exception. There, fourteen submarine lava-streams occupy perfectly distinct levels in the vertical scale, each one representing its own period of eruption, during a greater or less interval of time, and each one apparently preceded or accompanied by ejected fragmentary matter—by grit, ashes and mud, the greenstones being very commonly based upon a grit or breccia, at other times upon an ash or slate, each of them appearing to pass insensibly into the other. Mr. Williams particularly directed attention to the coast round Saltash, in the immediate vicinity of Plymouth, or from Redding Point to the great mass of porphyry near the fishing-houses, which was one uninterrupted series of varieties of volcanic ash, oftentimes passing into clay-slate, interstratified among the thick red sandstone beds seen on the east and west cliffs of the Sound. The lower beds of this sandstone Mr. Williams observed to be traversed by four north and south dykes, which cut the beds at right angles, and filled with the same rejectamenta that he had observed to constitute the partings between the sandstone beds; these he supposes may have been the vomitories through which the mud or ashes were blown out, as it was an interesting fact, that these ash-dykes did not traverse the more southern beds, but were overlaid and concealed by them.

On the discovery of Organic Remains, in a raised beach, in the Limestone Cliff under the Hoe at Plymouth. By E. MOORE, *M.D., F.L.S.*

The raised beach discovered under the Hoe by the Rev. Richard Hennah, has lately, by the extension of the quarry near which it was situated, been almost entirely removed, and in the progress of the work, it was ascertained to occupy a depression in the face of the limestone cliff, 100 feet wide and forty deep: its base is thirty-five feet above the present sea at high water spring tides; it runs upwards and backwards twenty feet, inclining inwards with the slope of the rock, and is covered by ten feet of gravel, thus making its entire elevation sixty-five feet above the present sea level. It is composed of fragments of rocks of the neighbouring shore, such as limestone, slate, red sandstone, and reddish porphyry, together with quantities of granitic sand, which is arranged in consolidated horizontal layers or false bedding with intervals of loose sand; a few shells (Patella and Buccinum) have been found in it; and recently, on its upper part, ten feet below the surface of the present soil, were discovered bones and teeth of the elephant, rhinoceros, bear, horse and deer; also caudal vertebræ of the whale, and the lower valve of a large oyster.

The quantity of fragments of leg-bones amounted to several bushels, being exceedingly fragile, and deprived of their animal matter; the whale's vertebræ and bear's tusks appeared much worn, as if by long-continued friction in water. Above and to the west of this deposit, eighty-eight feet from the present sea, is another accumulation of rounded quartz pebbles, ironstone, and sandstone, imbedded in a matrix of white clay, apparently differing altogether in character from the former, and assimilating to the deposits noticeable higher up the country about Barnstaple. The author described a continuation of the same accumulation several hundred feet to the westward, on a level with its lower line, composed of rounded masses of large size, mixed with sea-sand, containing numerous fragments of Purpura, Patella, Buccinum, &c., all similar to the Mollusca of the present sea; and then mentioned numerous instances of similar deposits occurring all around the shores of the harbour of Plymouth. Nearly the entire collection of bones was similar to those formerly obtained from the limestone caverns of Oreston, Yealm Bridge, Kitley, and Kent's Hole, all in this county. Dr. Moore inferred that the beach must have existed as such at the time when the animals of the caverns were in a living state: that it was really originally washed by the sea, he considered proved by the rounded form of the vertebræ of the whale and many of the bones; and from the marine shells deposited in it he believed that there must have been an elevation of the land at some former period, taking place slowly, not by any sudden convulsion, likely to destroy the animals then existing.

Account of the Strata penetrated in sinking an Artesian Well at the Victoria Spa, Plymouth. By EDWARD MOORE, *M.D., F.L.S.*

The author pointed out the mode by which the operations were conducted. The strata penetrated were as follows:—earthy clay-slate, 20 feet; limestone, 150; blue slate, 20; red sandstone, 3; red slate, 37; limestone, 50; sandstone, 4; red and blue slate, 30; dunstone, 8; earthy clay-slate, 20; red sandstone, 12; making a total of 365 feet. The earthy slates were of the character of those generally found under the limestone, but they were interspersed with blue shillat slates, similar to those which occur above it. From the circumstance of the slate rocks immediately below the red sandstone being in each instance tinged red, the author imagined that their colour might in these cases, if not in all, arise from the iron of the red bands affecting them by percolation. He next remarked, that from the alternations of slate and limestone, the former appearing, from a consideration of the section, to come up in wedges through the latter, it might be possible that the opinion that some of the Plymouth limestones might have been formed in a manner analogous to the modern coral reefs was founded on correct data, although in many other localities in the vicinity the bands belong to the same uninterrupted series of deposits. The quantity of water obtained was at first considerable, and overflowed the pipe; at present it generally remains about two feet below the surface, from whence it is carried to the saloon by a pump; it is clear and sparkling, and of a saline taste; it has been examined by Professors Faraday and Daniell, and found to contain in the imperial pint 8·100 cubic inches of carbonic acid gas, and 151·66 grains of dry salts, thus:—

Chloride of sodium	96·64
Muriate of magnesia	18·68
Muriate of lime	15·10
Sulphate of soda	9·55
Sulphate of lime	8·94
Carbonate of lime	2·06
Carbonate of iron	0·69
	151·66

Its specific gravity at 62° is 1013·3.

Dr. Moore exhibited a collection of the fossils just discovered in some of the slate rocks.

Notice of a series of Specimens from Mr. Johnson's Granite Quarries, near Prince Town, Dartmoor. By the Rev. Dr. BUCKLAND, *D.D., F.R.S.*

To the depth of ten or twenty feet the granite is more or less decomposed; surface granite of this kind has too frequently been employed, because it was cheapest; and the result is, that after a few years' exposure to a damp and foggy climate, as in the case of the prisons on Dartmoor, the decomposing granite becomes like a spongy mass, absorbing water continually, unless the walls constructed of it are externally covered with Roman cement or tiles. This defect is inseparable from granite, which is not quarried from a depth beyond the influence of decomposition. At the bottom of the Foggin Tor quarries a mass of virgin granite is laid open to a great extent, which is entirely free from this influence; and from hence the beautiful granite is obtained which is now in use for Lord Nelson's monument in Trafalgar Square. Dr. Buckland also exhibited a mass of amethystine quartz, from Dartmoor. He next described Earl Morley's quarries of potter's clay near Shaw, seven miles north of Plymouth. Here the surface, over hundreds of acres, consists of decomposed white felspar, which is purified by passing streams of water over it, and affords a fine porcelain clay of unusual purity, from which ornamental figures, &c. may be made, and which is largely exported to the potteries. Specimens of the decomposing felspar, and the porcelain prepared from it, were exhibited by Dr. Buckland; also firebricks made from the same clay in its natural state, which resist a stronger heat than Stourbridge bricks in the black bottle-glass furnaces.

On analysis, the Morley clay gives only silica, alumina, and water. The decomposing granite of the Morley Clay Works closely resembles that near St. Austle in Cornwall. Like the decomposed granite of Carcluse, near that town, it is also in some parts abundantly traversed by minute veins and insulated crystals of tin ore.

Dr. Buckland also exhibited water-pipes of a cheap kind, made from the coarser strata of decomposed granite that accompany the tertiary brown-coal at Bovey Heathfield, near Newton Bushell.

Mr. Dawson exhibited a model of the Great Landslip of Axmouth, which took place at Christmas, 1839. It was constructed on a scale of 120 feet to the inch, and represented a mile and a quarter. According to Mr. Dawson, the length of the chasm caused by this subsidence was 1000 yards, the breadth 300 yards, and the depth 130 to 210 feet; 22 acres were sunk in the chasm.

Mr. S. P. Pratt exhibited specimens, supposed to be from the slaty rocks overlying the limestone of Mount Batten; they were derived from blocks lying on the beach close to the black shales; one piece was in contact with the bed containing Encrinites. They contained several species of plants and scales of fish.

Major Harding read a notice of the discovery of some fossils on Great Hangman Hill, near Combemartin, North Devon. They consist of shells in the state of casts, and appear in large detached and ferruginous masses of quartzose rock, ranged on the surface. Major Harding has also observed a similar formation in the valley of rocks near Linton.

Mr. J. C. Bellamy exhibited a collection of Devonian fossils, containing about 150 species, and a printed table of genera, showing the various localities in which they were obtained; he stated the relative abundance of groups of fossils in these rocks, as occurring in the following order:—Polypiaria, Crinoidea, Conchifera, Cephalopoda, Gasteropoda, and Crustacea.

Notice of the Heave of a Copper Lode. By J. BOSWARRA.

On the Occurrence of some minute Fossil Crustaceans in Palæozoic Rocks. By JOHN PHILLIPS, *F.R.S., G.S.*

The freshwater limestones of Sussex and the tertiary beds have yielded great abundance of minute Crustaceans belonging to the same group with the *Cypris*, a small, bivalvular, pencil-footed animal, abounding in shallows of fresh water, where the warmth of the sun and abundance of decaying vegetable and animal matter conduce to their rapid multiplication. Beside these, there is a marine group called *Cythera*, and it is not easy to determine to which of these groups the fossil species belong; and in consequence the marine or fluviatile origin of the strata in which they occur is not always safely determinable from their occurrence. In the Weald of Sussex, and in the tertiary beds, their identification with the freshwater group is probably correct; but they occur also in situations not hitherto expected, and where the evidence remains to be examined. In the coal-shales of Yorkshire, which are 4000 feet thick, there occurs a band of marine shells, such as Goniatites, Orthoceras, and Pectens, without one freshwater shell, and above and below it, beds with indications, by shells, of fluviatile, if not decidedly freshwater origin; and the author noticed in 1831, that *Cyprides* occur mixed with the freshwater shells above the marine deposit. Dr. Hibbert described in 1834, to the British Association at Edinburgh, what he conceived to be freshwater *Cyprides* in the limestones of Burdie House; and in 1836 Mr. Phillips discovered vast abundance of *Cyprides* in the limestone of the upper coal-measures at Ardwick, north of Manchester, and immense numbers in black shales of the Bradford Collieries; and Mr. Binney has since found them in a great variety of situations. To the Dublin Geological Society (1840) Mr. M'Coy has announced thirteen or fourteen species in the mountain limestones of Kildare, which are full of marine organic remains. Mr. Phillips had lately observed in Pembrokeshire, in the lowest shales of the mountain limestone, within ten feet of the old red sandstone, beds of *Cyprides* very similar to those in the black shales of the upper coal-measures in Manchester. These are probably the most ancient specimens of the group yet discovered. The circumstances under which these Crustaceans are found at the present day appear to agree with those attending their occurrence in a fossil state; the recent *Cyprides* seem destined to consume the perishing parts of animal and vegetable substances; and the fossil species are generally associated with portions of fishes near Manchester, as observed at Ardwick by the author, and elsewhere by Mr. Binney, and by Dr. Hibbert at Burdie House. In Caldey Island they are in like manner associated with bone- and fish-beds. Probably their remains occur under many circumstances; but to ascertain all the conditions under which they lived, requires attention to many sorts of strata not often suspected to contain remains. Very remarkable conditions occurred when the old red sandstone ceased to be deposited; for then, after a long series of formations with no trace of organic remains, we find in the beds immediately above thousands of minute Crustaceans, bone-beds, layers of *Brachiopoda*, &c., of marine origin; and, encouraged by this example, we may expect to find them in beds of still higher antiquity.

Mr. J. Phillips remarked the fact of these cypridiform Crustaceans constituting the general type of *Entomostraca* through a large range of the strata, being in the older or palæozoic rocks unaccompanied by decapodous Crustaceans, which lie in later deposits, but flanked by a parallel series of Trilobites, which are absent from those newer strata.

On the genus Cardinia, *Agassiz, as characteristic of the Lias Formation.*
By H. E. Strickland, *F.G.S.*

Mr. Strickland called attention to a genus of bivalve *Mollusca* which is peculiarly characteristic of the Liassic series. This genus, which was named *Cardinia* by M. Agassiz in the 'Etudes critiques sur les Mollusques fossiles,' has also been termed *Pachyodon* by Mr. Stutchbury, and *Ginorga* by Mr. J. E. Gray. It appears to belong to the *Veneridæ*, and in external form approaches *Pullastra*, but is distinguished by possessing, in addition to the converging cardinal teeth, a pair of very strong lateral ones analogous to those of *Cardium*. From the ovate form of the shell and the structure of the hinge, the species of this genus have been referred by most authors to the *Unionidæ*, but are sufficiently distinguished by the lunule beneath the *umbo*, and by their marine habitat, as proved by the other fossils found in company with them. Ten or twelve species are known of this genus, the whole of which occur either in the marlstone or the lower lias. Seven of these species were exhibited; but as it was understood that Mr. Stutchbury proposed publishing a monograph of the genus, Mr. Strickland abstained from naming them before he had communicated with Mr. Stutchbury. The best known type of the genus is *C. Listeri* (*Unio Listeri*, Sow. Min. Con.). Mr. Strickland also exhibited the unique specimen of a dragon-fly's wing from the lias, the property of Mr. Gibbs of Evesham, figured in Mag. Nat. Hist. 1840, p. 301.

On the Geological Changes produced by the Saxicava rugosa *in Plymouth Sound. By* W. WALKER.

The *Saxicava rugosa* appears to be the prevailing perforator of the limestone rocks; and it is the author's opinion that these operations have been carried on during such long periods as to "destroy rocks, and make deep water where shoals previously existed." The different places in which the perforations had been extensive, or might be most advantageously examined, were described. The blocks of Portland stone, to which the buoys were formerly attached, were in two or three years punctured on the surface and also deeply perforated by the *Saxicava*; and in the sea-walls of Devonport dockyard, also of Portland stone, below the low-water level of spring tides, the stone is honeycombed and frittered away. Between the Devil's Point and Mount Edgecumbe the channel is 200 feet wide, and three or four times deeper than in the Sound. In using the diving-bell to cut away rocks in this channel, in order to form the sea-walls of the Royal William Victualling Yard, the limestone was found much perforated, and rocks brought up by the trawl from twenty and twenty-five fathom water were also perforated. The sides and bottom of this channel are of limestone, and the rapidity of the current keeps its surface clear; wherever this is the case, throughout the Sound, the bottom is found perforated by the *Saxicava*. The author then proceeds to show, that throughout the Sound there is a greater depth of water over the limestone rocks than over the red sandstone, and he attributes this degradation to the boring of *Saxicava*. The rocky shoals lying southward of a line drawn from Mount Edgecumbe through Drake Island to Mount Batten are composed of red sandstone, and lie from twelve to seventeen feet beneath the level of low-water spring tides. The depth of water over the anchorage, within the Breakwater, varies from twenty-seven to thirty-six feet; but immediately on passing the boundary-line of the sandstone, northward, the water becomes deeper, and where the rapidity of the tidal current prevents deposits of mud or sand, the depth varies from fifty to one hundred and twenty feet over the limestone.

The limestone hills around Plymouth were next described; and it appears that their elevation is generally less than that of the surrounding sandstone. These limestone heights at Stonehouse, Plymouth, Mount Batten, and Oreston, are nearly of the same elevation; raised beaches, rounded pebbles, and water-worn surfaces, furnish evidence of their having been once under water. Near the north-west corner of Drake Island is a small portion of limestone on a level with the ordinary high water, bearing traces of the perforations of *Saxicava*; and the rocky cliffs near Plymouth Citadel, from the low-water mark of spring tides, up to fifteen or twenty feet above high-water level, bear evidence of the same ravages; and at fifteen or twenty feet above the sea is a conglomerate mass of pebbles, sand and shells, and some limestone pebbles, perforated by *Saxicava*. At low-water mark are the animals in their holes, higher up their empty shells are seen, and above high water their perforations only are to be found. In the limestone in Hoe lake the author very recently found perforations by the *Pholas*, one hundred feet above the level of low-water spring tides. The situation was protected from atmospheric influence by a coating of earth and vegetation. From these circumstances the author inferred that all the limestone rocks around Plymouth were under water within the period during which the *Saxicava* was the great agent in the destruction of the rocks. In some cases the rocks are protected from these ravages by a coating of *Balani*, &c., which cover the rock; and in other places deposits of mud and sand are formed over the rocky bottom, and there the operations of *Saxicava* and *Pholas* necessarily cease. Since the Breakwater was erected, the water over the rocks near the Citadel has been diminishing in depth, from the accumulation of mud and sand, and an anchorage is forming where nothing but rocks previously existed. In conclusion, the author refers to the operations of boring shells on the mole of Castel à Mare in the Bay of Naples, and on other artificial structures, and suggests to engineers employed in the erection of public works, such as quays, docks, basins, or breakwaters, intended to last for centuries, the importance of considering whether limestone *of any kind* should be employed in such structures below the ordinary level of low water at spring tides.

Notice of Sections of the Railway between Bristol and Bath, a distance of twelve miles, prepared by direction of a Committee of the British Association. By WILLIAM SANDERS, *F.G.S.*

The first was in length thirty-six feet, being at the rate of three feet to the mile. The others were enlarged sections of four portions of the railway, made on the scale of forty feet to one inch. One of these represented a cutting one mile in length at Saltford, through the successive strata of the *lias* formation. This cutting was described by detailed sections on the scale of four feet to the inch; each bed is noticed with, as far as possible, its included organic remains. The subdivisions are, the *upper marl* upon *upper and lower blue limestones* fifty-eight feet, *white limestones* twenty-four feet, and *lower marl* twenty-seven feet; which latter were shown, by means of sinking a pit, to rest upon *new red marls*. Drawings of certain fossils were added. Three other enlarged views of the *Pennant* strata were given, with further details, in sections on a scale varying from twenty to ten feet to the inch. Drift beds were noticed containing water-worn fragments of sandstone, broken stems of plants (*Sigillaria* and *Lepidodendron*), with rolled pieces of perfectly formed coal; also conglomerates of broken coal. Drawings were made of two large *Sigillariæ* taking origin in a bed of coal; and a portion of two large slabs of the Pennant sandstone, showing very regular *ripple-marks*. Various other geological phænomena deemed worthy of attention were displayed on the sections.

Notice of Sections of the Railways between Glasgow and Greenock, and Greenock and Ayr, prepared by direction of a Committee of the British Association. By JOHN CRAIG.

A Letter was read from T. B. JORDAN, *of the Museum of Economic Geology, 'On Copying Fossils by a Galvanic Deposit.'*

In applying the method ordinarily used in electrotyping, some difficulty was experienced by the author in consequence of the irregular form of the fossils, parts of which would not relieve from the wax or plaster matrix in which the copper is afterwards deposited. Mr. Jordan therefore adopted a compound of glue and treacle (used by printers for their inking-rollers) as the material of the moulds, the elasticity of which admitted of its leaving the adherent portions without breaking. The mixture is applied hot, and allowed to harden for twenty-four hours, when it will come off without injuring the finest parts. The matrix thus prepared requires a strong varnish to protect the back and sides from the action of the liquid in which it is to be placed, and only one copy can be made from each matrix; but the impressions have none of the defects so apparent in those produced in the ordinary moulds. Different lights and shades may be given to the copper impressions by a galvanic process, which the author considers capable of improvement and application to other purposes. For a dark object on a light ground the surface is brushed over with the argento-cyanide of potassium, giving it a silver face, which may be removed to the desired extent from the portions requiring to be dark, by a dilute solution of nitro-muriate of platina. Other tints may be produced by using a solution of gold; and all may be considerably varied by changing the time during which each solution is allowed to act.—[Specimens of the electrotype copies of Trilobites and other fossils were exhibited.]

Notice of Models for Illustration of the Succession and Dislocations of Strata, Mineral Veins, &c., constructed by T. Sopwith, F.G.S. By the Rev. Dr. BUCKLAND.

Major S. Clerke called attention to the 'Atlas of Sieges and Battles in the Peninsula,' published by Mr. Wylde, and constructed from original sketches taken under the direction of Sir George Murray, by Sir Thomas Mitchell, now Surveyor-general of New

South Wales. Major Clerke explained the origin and character of these plates, which he designated as a noble specimen of military topography.

Mr. H. E. Strickland communicated to the Section a map of Santorin, about to be published by Prof. Ritter of Berlin. It is engraved from a survey of the island made by Capt. Gineste, officer of the French expedition in Northern Greece.

ZOOLOGY AND BOTANY.

On the Zoology of the County of Cornwall. By JONATHAN COUCH, *F.L.S., &c.*

Of the fourteen or fifteen species of *Cheiroptera* enumerated as British by Mr. Bell, six are included in the Cornish fauna, and one more (*V. discolor*) has been found at no greater distance than Plymouth. Of the remainder, eight are too limited, in numbers and distribution, to enter into a calculation of comparison with other parts of the kingdom. The commonest of the Cornish Bats are, the Pipistrelle, Lesser Horse-shoe, and Long-eared, in the order in which they are enumerated; but their local occurrence depends more on the accident of their meeting with congenial haunts, than on the mere influence of climate. The latter circumstance, however, produces its effect on the habits of these animals; so that in Cornwall, where what may be denominated severely cold winters do not occur more frequently than in cycles of six or eight years, the appearance of the bat may be witnessed in every week in an ordinary year. A fall below the 40th degree of the thermometer is the signal for their retreat; but a slight change to a milder temperature restores them to activity, when not uncommonly they may be seen at midday in search of prey, which might not be obtained at the more usual hours of the evening.

It may be regarded as another proof of the mildness of the climate, that the Long-tailed Field Mouse (*Mus sylvaticus*) breeds at Christmas, or the very beginning of January, forming its nest at this time in ricks of hay. The frog also is rarely later than this period in depositing its spawn.

Of the genus *Sorex*, Cornwall possesses three species, sufficiently distinguished. These are, *Sorex araneus*, Jenyns, in the Mag. of Zoology, vol. ii.: the front teeth of a deep brown through most of their length, Bell's Br. Q., p. 109. Another species, *S. araneus* of Duvernoy and Jenyns, Mag. Zool. vol. ii. f. 1.: the snout not so long as in the *S. araneus* of English authors; the teeth brown only at the tips of the lower front teeth and of the molars. A third is referred to *S. Fodiens* of Bell, *S. bicolor* of Jenyns, Mag. Zool. vol. ii. p. 37, but differing in some particulars; more especially in having the under front teeth purely white, the upper slightly coloured. Of birds, there are known in Cornwall 243 species; of fishes, 173; of stalk-eyed Crustaceans, 67.

The additions to the zoology of the West of England which this enumeration implies, with those belonging to the radiate animals, will be given in a second part of the Cornish fauna, now proceeding through the press.

On the Distribution, &c. of the Mammals of Devonshire. By J. C. BELLAMY.

The author exhibited a drawing of the palate of an individual of *Balænoptera minor* (Knox), taken off Plymouth, and showed a portion of the baleine, and a part of the ear of that animal. He showed a new species of Vole, taken at Yealmpton. He also displayed a tooth of an extinct species of elephant, from the Yealm Bridge cavern; a species of *Asterias* unknown to him; a species of *Helix* new to the British isles; some *Helices* from the Yealm Bridge cave (proving their modern date); the skull of *Arvicola agrestis*, having teeth with fangs, instead of the common fluted condition; and several curious relics of *Arvicolæ*, birds, fish, &c. from the cavern of Yealm Bridge, which he discovered.

On the Geographical Distribution of the Animals of New Holland. By JOHN EDWARD GRAY, *F.R.S.*

"If in our collection and catalogues we were to mark all the species found in Europe as coming from England, we should be nearly as correct as we are at present in the determination of the localities of the Australian animals, for almost all the specimens are marked as coming from New Holland. This is not only the case with the specimens contained in the museums, but also with respect to the observations of some recent voyagers. Having recently received at the British Museum a complete series of all the Mammalia collected by Mr. Gould during his visit to Australia, and of those sent from his collector, Mr. Gilbert, from Western Australia, all the specimens of which were marked at the time they were collected, I have been induced to draw up a few remarks on the geographical distribution of these animals. From these materials, and others at my command, I believe there are at present known ninety species of Mammalia found in Australia, belonging to thirty-six genera: of these, seventy-seven species, belonging to twenty-one genera, are marsupial, three species and two genera are monotrematous, and twenty-three species and twelve genera are non-marsupial; eight of these twenty-three species and four genera are Bats belonging to the order *Primates*; two species belonging to two genera of *Feræ* or carnivorous beasts, as the Dog and the Seal; and the remaining eleven species, referable to four genera, are Mice belonging to the *Glires*, and two to *Cetæ*, or Whales. Of these thirty-three genera found in Australia, seven, as *Chœropus*, *Acrobates*, *Petaurista*, *Lagochestes*, *Phascolarctos*, *Pseudomys*, and *Harpalotis*, are peculiar to New South Wales. *Petaurus* might be placed in the same group; but a single species is also found in Norfolk Island, where it is the only known beast. It is by some supposed to have been introduced from Sidney, especially as it is not found in Van Diemen's Land. The genera *Bettongia* and *Petrogale* are only found in New South Wales, South Australia, and the north coast; and the genus *Myrmecobius* is peculiar to Western Australia; so that these ten genera are peculiar to the Australian continent. The genera *Thylacinus*, *Diabolus*, and *Dromicea* are peculiar to Van Diemen's Land. The genera *Dasyurus* and *Perameles* are common to Van Diemen's Land and the continent, but much more abundant in the former. The genera *Nyctophilus*, *Phalangista*, *Phascogale*, *Hepoona*, *Macropus*, *Halmaturus*, *Hypsiprymnus*, and *Hydromys*, appear to be common to the continent of Australia and Van Diemen's Land, as also appears to be the case with the genera *Echidna* and *Ornithorhynchus*; but the two latter genera have not yet been discovered in South Australia. There are some species found in Australia which belong to genera, as *Pteropus* and *Rhinolophus*, which are found in different parts of the Old World; and others, as *Canis*, *Mus*, *Scotophilus*, and *Molossus*, which are common to it and both hemispheres. One genus, *Halmaturus*, has a species found in New Guinea; but most probably, when this species has been more carefully examined, it will be found to form a peculiar genus allied to the Australian one, as is the case with the tree Kangaroos (*Dendrolagus*) and the Phalangers (*Cuscus*) of that country; and is also probably the case with the *Perameles*, said to be found in New Guinea. If we examine the distribution of these ninety-seven species over the different parts of the country, we shall find that sixty species inhabit New South Wales, of which forty-five are peculiar to it, and fifteen common to it and other parts of the country. Eighteen species inhabit South Australia; six are peculiar, and twelve common to other parts. Twenty species inhabit Western Australia; twelve peculiar, and eight common. Six species inhabit the north-west coast, all of which are peculiar to it. Three species inhabit the north coast, two of which have not been found elsewhere. Twenty-two species are found in Van Diemen's Land; eleven only are found in this country, and eleven common to it and the continent. One species is found in Norfolk Island, which is also found in New South Wales, but not in Van Diemen's Land. The species peculiar to the north-west coast are *Macropus unguifer*, *Halmaturus Bennettii*, *H. fasciatus*, *Petrogalea brachyota*, *Hyp. Lesuerii*; to South Australia, *Phascogalea rufogaster*, *Macropus fuliginosus*, *Halmaturus Derbianus*, *Bettongia Grayii*, *Mus Grayii, and M. Adelaidensis*; to Western Australia, *Myrmecobius fasciatus*, *Phascogalea leucogaster*, *Perameles fuscoventer*, *P. obesula* and *P. Lagotis*, *Halmaturus brevicaudatus*, *Petrogalea lateralis*, *Hypsiprymnus Gilbertii*, *Bettongia Ogilbii*. *Macropus laniger* and *Mus lutreola* are peculiar, as being common to the east and south sides of the continent. *Scotophilus Australis*, *Hydromys chrysogaster*, *Phalangister Vulpina*, and *Hepoona Cookii*, have the largest range, as they are common to the south, west, and east sides of the continent; and the two latter are also found in Van Diemen's Land*."

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* Mr. Gray has given a more detailed paper on this subject in the Appendix to Capt. G. Grey's Journal of two Expeditions of Discovery in Australia, 1841.

On a New Glirine Animal from Mexico. By J. E. GRAY, *F.R.S.*

The British Museum having lately received from Mr. John Phillips, of the Reale del Monte Mining Company, a new glirine animal, which he brought from Mexico, I am desirous of mentioning it before this meeting, not only on account of its being new to our zoological catalogues, but also because it illustrates two interesting facts, one in the geographical distribution of animals, and the other of certain genera being represented in different parts of the world by animals very similar in external appearance, but yet possessing peculiar characters adapting them to their different localities.

The animal before us is peculiar for having large cheek-pouches, which open externally on the sides of the cheek. This conformation has only hitherto been observed in four genera of glirine animals, which exclusively inhabit the northern half of the American Continent, as the genera *Saccophorus*, *Saccomys*, *Anthomys*, and *Heteromys*. These cheek-pouches are used by the animals to carry their food, as the Monkeys of the Old World use their internal pouches which are found between their cheeks and the mouths. The first of these genera has been long known; and it has been believed that their cheek-pouches hung out of the side of the cheek-like pockets; but this does not appear to be the case with the genus under consideration, or with *Anthomys*, which was so called because M. F. Cuvier found their cheek-pouches filled with flowers.

If it was not for these cheek-pouches, the animal before us might be taken for a Jerboa (*Dipus*), with which it perfectly agrees in the softness and colour of the fur, and in the length of the hind legs and the tail, which has a brush at the end, so that it may be at once distinguished from the other American genera above enumerated, which either have an elongated scaly tail like a rat, or a very short one like a lemming. I am therefore inclined to consider this animal as the American representative of the genus *Jerboa* (*Dipus*), which is confined to the more temperate part of Africa, as the genus *Harpalotis* is the representative of the same genus in Australia. This combination of the forms and colour with the Jerboa, and with the external cheek-pouches of the pouched rat, at once marks this animal as a new genus, which I propose to call *Dipodomys*, or Jerboa Rat, designating the species after its discoverer, *Dipodomys Phillipii*.

Mr. Gray exhibited a skin of glove leather from Sweden, prepared from the skin of the fœtal Rein-deer by tanning with birch bark.

Account of a Thylacinus, *the great Dog-headed Opossum, one of the rarest and largest of the Marsupiate family of Animals. By Professor* OWEN.

At the present day this animal exists only in Van Diemen's Land, though formerly it had a much more extensive geographical distribution. For his knowledge of the anatomy of this animal, Mr. Owen stated that he was indebted to Sir John Franklin, who had kindly preserved and sent him a specimen in spirit, and he believed this was the only specimen extant in Europe. In its habits it was carnivorous; holding about the same relation to the other Marsupialia that the digitigrade Carnivora did to the placental Mammalia. It was a great pest to the shepherd in its native districts; and in its low intellectual character, and its craft and cunning, very much resembled the wolf. In destroying sheep it does not feed on them at once, but proceeds to worry, if possible, the whole flock, first tearing one and then another. Its smell is very powerful. It has a narrow head, a large number of incisor teeth, with the molars more numerous and uniform in size and shape than in the wolf. The incisors are of equal length and regularly arranged in the segment of a circle, with an interspace in the middle of the series of both jaws. The external incisors on each side are the strongest. The laniary or canine teeth are long, strong, curved and pointed, like those of the dog tribe. The spurious molars in this, as in all other Marsupials, have two roots; their crown presents a simple compressed conical form, with a posterior tubercle, which is most developed in the hindmost. The true molars in the upper jaw are unequally triangular, the last being much smaller than the rest; the exterior part of the crown is raised into one large pointed middle cusp and two lateral smaller cusps obscurely developed; a small strong obtuse cusp projects from the inner side of the crown. The molars of the lower jaw are compressed, tricuspidate, the middle cusp being the longest, especially in the two last molars, which resemble closely the sectorial teeth (*dents carnassiers*) of the dog and cat. The following is the dental formula of the *Thylacinus*:—incisors $\frac{4-4}{3-3}$; canines $\frac{1-1}{1-1}$; premolars $\frac{3-3}{3-3}$; molars $\frac{4-4}{4-4}$; $= 46$. Its bony palate is very defective, thus presenting a lower organization than any of the Carnivora of Europe. Its internal organization agrees with that of *Dasyurus* and *Phascogale*, being, as in these carnivorous Marsupials, destitute of a cæcum: it differs from *Dasyurus* and resembles *Phascogale* in having the internal condyle of the humerus perforated. It has the pouch so decidedly characteristic of the whole order of these animals. The reason of the existence of this pouch may be to enable the animal to carry its young great distances more easily, as it was obliged to travel far, in seasons of drought, in search of water. The pouch is usually limited to the female; but in *Thylacinus* a rudiment of the pouch exists in the full-grown male.

Notices and Drawings of three new Genera of Marine Fishes from Van Diemen's Land. By J. Richardson, *M.D., F.R.S.*

1st. *Nemadactylus*, or Thread-finger. This acanthopterygian genus agrees with *Cheilodactylus* in the lower rays of the pectoral fin being simple, with one prolonged beyond the others, and in the general form of the body; but differs from the percoid family in general in the perfectly unarmed gill-covers, feeble dentition, and scomberoid character of all the scales below the lateral line. The fauces, palate and tongue are smooth, the margin of the mouth exhibiting a single row of slender minute teeth. The intermaxillary pedicles are short, the gill-rays only three; the pyloric cæca likewise three, and the spinal vertebræ thirty-four. The only species known is named *N. concinnus*, and but one specimen was obtained. Length 3½ inches. Its stomach contained fragments of malacostraca.

2nd. *Latris* has a mœnoid aspect, but differs from the rest of that group in the inferior half of the pectoral rays being simple, and in the combination of certain characters, which, though existing, and indeed rather characteristic of the family, are not all found in any one genus. It is most nearly allied to *Cheilodactylus*. The species described is named *Latris hecateia*, or Six-banded Trumpeter. Two species of this genus appear to be represented in Nos. 204, 205, and 209 of the drawings made on Cook's second voyage at New Zealand: they bear the MS. names of *Sciæna lineata* and *Sciæna ciliaris*. The drawings do not exhibit the structure of the pectorals distinctly, yet the other details are so correct, that there seems to be no reason for doubting their position in the genus *Latris*. *Sciæna lineata* has the precise markings of *L. hecateia*, the species described in this paper, and may be identical with it. The Van Diemen's Land fish is named the Trumpeter by the colonists, and is esteemed as their best fish. The figure 205 above referred to has the word "*sapidissimus*" written beneath it in Forster's hand.

3rd. *Hoplegnathus*, a scaroid fish, departing greatly from the usual aspect of the fish of this family. In dentition and form of the jaws this genus approaches more nearly to the typical *Scari* than to *Odax*. But the scales of the body are small, the bases of the vertical fins are densely scaly, with fillets of minute scales stretching up between the rays. The spinous rays are very unlike the flexible ones of *Odax*, being stronger than is usual even in *Scarus*, and the lateral line is continuous. This fish was brought to England by the surgeon of a convict ship, but as he is since dead, the locality in which it was taken cannot be now ascertained.

Full descriptions, with figures of these fish, are to be published in the forthcoming volume of the Transactions of the Zoological Society.

On the Habits of the Eel, and on the Freshwater Fish of Austria. By Captain Widdrington, *R.N.*

The author stated that his attention was drawn to the subject by a remark of Mr. Yarrell in his work on British Fishes, in which he ascribes the deficiency of eels in the Danube to the excessive susceptibility of the eel to cold. The author had seen eels at Wurzburg on the Mayn, where the average degree of cold is quite as great as that of the Danube. They also exist in the Elbe, at a point where that river would also be colder than the Danube. They exist undoubtedly in the higher branches of the Danube, but not in the delta. This, the author thinks, may be ascribed to the nature of many of the waters which fall into the Danube, which, being alpine in their character, possess little nutriment fit for the nourishment of the fish. Most alpine streams are composed of melted snow or rain-water, and possess few constituents that will afford nutriment to fish, more especially the eel, and thus their absence may be easily accounted for. The same remarks apply to the Rhine, which is completely alpine in its character till it reaches the Moselle. The author announced that Prof. Heckel was about to publish a work on the freshwater fishes of Austria, which would contain some new genera and a large number of new species.

Dr. T. Thomson exhibited two living specimens of Lepidosiren which he had taken in Macartney Island, on the Upper Gambia. They were found lying imbedded in a hole in the rock, from which they could only be removed by a hammer. They were almost covered with a coat of mud, which one of the specimens still retained.

Dr. Tripe exhibited some specimens of *Pontia*. In their marking they resembled *P. Rapæ* and *P. Napi*, but were very much smaller. In some points of structure they differed from the large species. The club of the antennæ was less abrupt, and the wings were more square in their form. They had only been found during very hot and dry summers in one locality near Whitsand Bay. In wet seasons they were never seen. They were mostly found feeding on the blackberry.

On two remarkable Marine Invertebrata inhabiting the Ægean Sea. *By* E. FORBES, *F.L.S.*

These animals were taken in the harbour of Nousa, in the island of Paros, which is extremely rich in marine productions. The depth of the bay is generally from seven to ten fathoms; the bottom sand and weed. The animals differ according to bottom and depth. Amongst the sandy heaps at the bottom of this bay are two new animals. The first a zoophyte of the family *Actiniadæ*, which is free and vermiform, and which lives in a tube of its own construction,—a combination of characters hitherto unnoticed among the helianthoid polypes. The second is a tubicolar annelide, which lives in a strong gelatinous tube, bearing a remarkable analogy to the sac of certain Entozoa. These two animals are noticed together, as in each case the peculiarity of the organization and habits is the result of a similar adaptation of form, in two very distant tribes, to a similar locality. In the absence of works of reference, the author abstained from giving names to these animals, although he believed them to be new, both generically and specifically.

On Deposits in Springs, Rivers, and Lakes, from the existence of Infusoria. *By* E. LANKESTER, *M.D.*

Dr. Lankester communicated some additional observations on the existence of organic beings in mineral waters. He had found the *Conferva nivea* of Dillwyn in the sulphur spring on the river Leith near Edinburgh. He had also found it in the wells of Moffat in Dumfries-shire, Gilsland in Northumberland, and Middleton and Croft in Yorkshire. At Moffat he found great quantities of the substance called *glairine*, and was convinced of its organic nature. At Moffat also he found a pink deposit in the drains outside the wells, and on submitting it to the action of the microscope, he found that it was produced by an animalcule, but much smaller in size than those which produced the coloured sediments of Harrowgate and Askern. It had the characters of a *Monas*, and was not more than $\frac{1}{15000}$th of an inch in diameter.

On Cecidomyia Tritici. *By Prof.* HENSLOW, *F.R.S.*

Prof. Henslow invited the co-operation of members in his attempts at perfecting the natural history of the Wheat-Midge (*Cecidomyia Tritici*). He stated that he had not been able to breed a single fly from many hundred larvæ which he had procured from the barns in his neighbourhood, during the winter months, by sifting the chaff immediately after the corn had been dressed. Mr. Curtis had been equally unsuccessful. The inquiry to which he was anxious to direct the attention of naturalists was, whether the flies which appear in myriads during the first week of June and then deposit their eggs in the ears of wheat, have proceeded from larvæ which had entered the ground, and had there assumed the pupa state, or from larvæ which were housed in great profusion with the corn; and lay concealed in the ears. He considered it of importance to determine this point correctly, as the possibility of checking the pest probably depended upon the result. The Professor then exhibited specimens of *Puccinium graminis* (Mildew) in connexion with *Uredo rubigo*; *Aregma rosæ* in connexion with *Uredo rosæ*; and *Phragmidium obtusum* in connexion with *Uredo potentillæ*, for the purpose of illustrating and confirming an opinion he had advanced in the Journal of the Royal Agricultural Society,—that rust and mildew were produced by the same fungus; and also of showing generally, that many of the species referred to the genus *Uredo* were probably only imperfect states of certain fungi belonging to *Puccinium* and other allied genera.

On the Colossal Sepiadæ. *By Col.* HAMILTON SMITH, *F.R.S.*

The author detailed what was known at the present day of the existence of animals of enormous size inhabiting the ocean, belonging to the class of Cephalopods. However incredulous some naturalists might be with regard to the existence of these animals, the author had collected sufficient evidence to convince him that animals of a very large size belonging to this class now inhabited the waters of the ocean. The paper was illustrated by numerous drawings, and one was a sketch of the beak and other parts of an enormous Sepia, still preserved at the Museum of Haarlem, where they were seen by the author.

Projet d'observations annuelles sur la Périodicité des Oiseaux. *By* M. EDM. DE SELYS LONGCHAMPS.

M. Quételet, directeur de l'observatoire de Bruxelles, et Sécretaire perpétuel de l'Académie des Sciences de Belgique, vient de faire un appel à toutes les sciences physiques pour étendre à leurs diverses branches le système d'observations périodiques et comparatives qu'il a mis en pratique déjà depuis longtemps en prenant pour point de départ la météorologie et le magnétisme terrestre.

La zoologie et la botanique devaient les prémières être interrogées pour que l'on pût s'assurer chaque année jusqu'à quel point les variations dans la constitution météorologique peuvent avancer ou retarder l'apparition de certains animaux, ou la feuillaison et la floraison des plantes.

Les naturalistes Belges se sont empressés de réaliser le désir du savant Astronome en reconnaissant en outre combien ces observations, avec des dates précises, et répétées pendant plusieurs années, rendront plus exactes les *moyennes* que l'on cherche à indiquer dans les faunes et les flores locales, je dirai plus, dans la faune générale de l'Europe. Car si les zoologistes des diverses régions de cette partie du monde répondent à notre appel, combien ne sera-t-il pas intéressant de pouvoir tracer sur une carte géographique le voyage annuel des Hirondelles, des Grues, et de tant d'autres oiseaux voyageurs de long cours dont chacun de nous ne peut parler que vaguement faute d'observations comparatives.

C'est dans le but d'assurer la possibilité de ces comparaisons que je crois utile pour l'ornithologie, la branche dont j'ai à parler aujourd'hui, d'inviter sérieusement les ornithologistes à concentrer leurs observations sur un certain nombre d'espèces qui sont répandues dans toute l'Europe ou à peu près. J'ai cru devoir pour cette raison choisir des espèces terrestres de préférence aux aquatiques, parceque leurs migrations s'étendent avec plus de régularité sur toutes les régions, et que leur détermination est plus facile au point que lorsqu'on habite la ville on peut faire les observations par de simples chasseurs, tous ces oiseaux ayant un nom vulgaire dans les divers dialectes Européens. Je suis loin de nier l'utilité d'observations semblables sur les migrations des oiseaux d'eau, mais, je le répéte, je crois que pour les prémières années on aurait peine (faute d'un assez grand nombre de stations) à recueillir des données suffisantes pour en tirer des résultats généraux sur ces espèces, qu'on ne trouve régulièrement que dans les grands marais ou sur les côtes maritimes.

Je proposerai donc d'étudier, à partir de 1842, la date précise des migrations des 40 espèces suivantes, que l'on peut répartir en quatre sections. 1. Les oiseaux qui viennent passer l'été chez nous et y nicher, comme l'hirondelle et le rossignol. 2. Ceux qui sont de passage régulier, mais qui ne font que passer sans s'arrêter, comme la grue et le pluvier. 3. Les oiseaux qui séjournent tout l'hiver dans notre pays et disparaissent pendant la belle saison, comme la corneille (*Corvus cornix*) et le tarin (*Fringilla spinus*). 4. Les oiseaux de passage accidentel à des epoques indéterminées,

comme le jaseur (*Bombycilla garrula*) et l'oiseau de tempête (*Procellaria pelagica*). Je me suis départi des principes mentionnés en indiquant cette dernière classe d'oiseaux, mais j'ai cru qu'il serait important de porter l'attention sur deux ou trois espèces dont les causes d'apparition sont absolument inconnues, comme le jaseur, ou sont tout à fait en rapport avec l'existence de tempêtes maritimes, comme l'oiseau de tempête. La première section sera, je pense, la même pour toute l'Europe, mais il n'en sera pas de même des trois autres ; ainsi dans telle contrée comme en Hollande, par exemple, la cigogne sera de la première, tandis qu'ailleurs, comme en Belgique, elle sera de la seconde. Il en sera de même des troisième et quatrième sections selon la latitude plus ou moins septentrionale dans laquelle seront faites les observations, et c'est justement ces rectifications qui feront, je l'espère, apprécier l'utilité du travail que nous désirons voir entrepris.

Liste des Oiseaux choisis pour l'Observation.

I. *Oiseaux qui passent l'été en Belgique.*

1. Cypselus apus.
2. Hirundo urbica.
3. ——— riparia.
4. ——— rustica.
5. Muscicapa grisola.
6. Lanius rufus.
7. Oriolus galbula.
8. Emberiza hortulana.
9. Motacilla alba.
10. ——— flava.
11. Saxicola rubetra.
12. ——— œnanthe.
13. Sylvia Tithys.
14. —— phœnicurus.
15. —— luscinia.
16. —— atricapilla.
17. —— trochilus.
18. —— hippolaïs.
19. —— palustris.
20. Upupa Epops.
21. Cuculus Canorus.
22. Columba Turtur.
23. Perdix coturnix.
24. Crex pratensis.

II. *Oiseaux de passage double et régulier au printemps et en automne.*

25. Muscicapa ficedula (luctuosa, Tem.).
26. Turdus Torquatus.
27. Charadrius pluvialis.
28. Ciconia alba.
29. Grus cinerea.
30. Scolopax rusticola.

III. *Oiseaux qui séjournent tout ou partie de l'hiver en Belgique.*

31. Corvus cornix.
32. Fringilla spinus.
33. Fringilla montifringilla.
34. Anthus obscurus.
35. Regulus cristatus.
36. Parus ater.
37. Anser segetum.

IV. *Oiseaux de passage accidentel.*

38. Bombycilla garrula.
39. Procellaria pelagica et Leachii.
40. Cygnus musicus.

Liége, 10 Juillet, 1841.

Specimen.

Oiseaux observés à Liége au printemps de 1841.

1841. Mars 8. Scolopax rusticola, passage jusqu'au 20.
16. Motacilla alba, arrive.
26. Sylvia Tithys, *id.*
28. Sylvia Trochilus, *id.*
Avril 1. Sylvia luscinia, arrive.
id. Regulus cristatus, } émigrent au nord.
id. Fringilla spinus, }
12. Upupa Epops, }
13 au 18. Hirundo rustica, }
22. Sylvia curruca }
23. Cuculus Canorus, } sont arrivés.
id. Columba Turtur, }
28. Oriolus galbula, }
id. Perdix coturnix, }
Mai 1. Hirundo riparia, }
id. Hirundo urbica, }
id. Cypselus apus, } sont arrivés,
id. Sylvia atricapilla, }
id. Muscicapa grisola, }
4. Sylvia hippolaïs. }
Vers le 15 Mai, Sylvia palustris.

[It is requested that observations made as recommended by M. de Selys Longchamps, be communicated to the Zoological and Botanical Section at the next Meeting of the Association.]

Description of two Peruvian Mummies, presented to the Devon and Cornwall Natural History Society by Captain Blanckley, of the Royal Navy. By P. F. Bellamy, *M.D.*

They proved to be the remains of children of different ages, one a few months old, and the other not much more than one year; they were brought from the mountainous district of Peru, but at a considerable distance from the Lake Titicaca. In conjunction with them were found certain envelopes (one of which proved to be an article of dress, resembling a ponshad sewed up at the sides), and the model of a raft or catamaran, two small bags containing ears of an undescribed variety of Indian corn, and two small earthen pots. He also exhibited a variety of other models, found wrapped up with others examined by Capt. Blanckley. The skulls were found to resemble those adult specimens contained in the museum of the Royal College of Surgeons in London, and presented the same peculiarities,—viz. a short projecting face, square protruding chin, receding forehead, and elongated cranium. He stated that he considered their formation to be natural, for the following reasons:—1st, that the peculiarities are as great in the child as in the adult, and indeed more remarkable in the younger individual than in the elder; 2nd, from the great relative length of the large bones of the skull, all of which are elongated in a posterior direction; 3rd, from the position of the occipital bone, which occupies a place in the under part of the cranium; 4th, from the absence of marks of pressure, there being no elevation of the vertex, nor projection on either side; and 5th, from there being no instrument, nor mechanical contrivance, suited for the process of compression found in conjunction with the remains. He called the attention of the Section to the peculiar formation of the occipital bone, which he found to consist of five rudimentary portions, the fifth piece being placed between the occipital portion, commonly so called, and the two parietal bones. He considered the probability of the mummies being the remains of some of the true Titicacan race, deposited after the arrival of the original emigrants, who founded the Incas dynasty, and called on ethnologists to say what Asiatic people they resembled in manners, customs, and attainments; but if no affinity could be found, he considered it fair to attribute to the indigenes a mental capacity equal to the originating of such inventions as the specimens connected with these mummies would indicate them to have been capable of. The extinction of the race he supposed to have been gradual, and occasioned by an intermixture of blood with the followers of Manco Cape. Lastly, he suggested that the adult skulls called Titicacans were of two kinds, one being of the pure stock, the other of a spurious character, resulting from the union of the indigenes with the settlers of Asiatic origin, and presenting a modified form; there being added to the receding forehead and elongated cranium, an elevated vertex and flattened occiput, formed principally by an altered position of the occipital bone, which, instead of lying on a plane with the horizon, rises in a sloping direction upwards and backwards.

On the Varieties of the Human Race. By Dr. Caldwell.

Considering that this subject had been too much neglected, the author proceeded to give an example of the method by which he thought it ought to be treated, by a comparative view of the anatomical structure of the African and Caucasian varieties of Man. After dwelling minutely on the anatomical structure of the two races, he stated his conviction, that the former bore anatomically a nearer resemblance to the higher Quadrumana than to the highest varieties of his own species.

Remarks on the Flora of Devon and Cornwall. By the Rev. W. S. Hore.

Jones's 'Flora Devoniensis,' published about twelve years ago, has served as a basis for the Flora of the two western counties of Devon and Cornwall, which, from their position, form one of the districts into which Great Britain would naturally be divided by the geographical botanist. The number of Phanerogamous species recorded by Jones is 774. Forty-one additional species are now enumerated for Devon, and thirty-one for Cornwall, which would raise the number of plants indigenous to the two counties to 846. The most interesting discoveries since the time of Jones, are *Arthrolobium ebracteatum, Trichonema columnæ, Viola Curtisii, Chrysocoma Linosyris, Trifolium Bocconi,* and *Hypericum linarifolium. Phycospermum Cornubiense,* hitherto supposed to be limited to the neighbourhood of Bodmin, is now mentioned as growing near Tavistock in Devon. The old habitat of *Scirpus Noloschenus* on Brampton Burrows has been destroyed by the shifting of the sand. A new spot, where the plant is in some abundance, has, however, been exposed by the same cause. It is not improbable that ere long it may become extinct.

On some Species of European Pines. By Capt. WIDDRINGTON, *R.N.*

In a paper on European Pines, read at Newcastle, the author did not allude to two species, as he had not seen them, viz. *Pinus austriaca* and *P. Pumilio.* Opportunities of observing them have since presented themselves. *Pinus austriaca* of English, *P. nigrescens* of the German botanists, partly covers the plain of Austria to the south and east of Vienna. It is also found in Austria on the borders of Styria, and clothes the hills near Baden. It does not appear to the north of this, and in considering its elevation and geography, it must be placed in the zone below *Pinus sylvestris*; at the same time there can be no question that it would withstand the cold of these islands. It is very nearly connected with *P. taurica*, or *Pallasiana*; the foliage is scarcely to be distinguished. There is, however, a very perceptible difference in the form of the cones in cultivated species. From the quick growth of this tree, the great beauty of its foliage, thick and tangled, and of the deepest green, as well as the great value of the timber, which Austrian woodmen consider superior to that of *P. sylvestris*, Mr. Lawson of Edinburgh introduced this species. It may be planted in most places as a substitute for the Pinaster, to which it is much superior, both in timber and appearance. *Pinus Pumilio* is a native, though sparingly, of Upper Styria; it is most abundant in the Bavarian Alps. It inhabits marshy districts and the borders of lakes, as well as dry gravelly situations. The peculiar form of this tree consists in its having no regular leader. It divides into a number of small stems and branches immediately above the ground. The height attained is rarely more than five or six feet, and the diameter of all the branches of the largest trees is not more than twenty or twenty-five feet. It grows so regularly, that, on looking over an extensive level planted with it, it is quite as even as the level of a gorse cover. The foliage, in form and colour, resembles that of *P. uncinata,* but the spicula are shorter. The cones are small and dark-coloured, and differ from those of *P. sylvestris* and *P. uncinata.* It is frequently confounded with stunted varieties of other pines. Its position in geographical range is by the side of *P. Cembra* and *P. uncinata.*

Notice of destruction of Plants by Animal Odour. By ROBERT BALL, *F.L.S.*

"Having obtained a very young porpoise (*Delphinus phocæna*) a few hours after it was killed, I became anxious to get the immature bones of its skull without the trouble of dissection, or the loss of time in maceration. Accordingly I placed the head in an earthen crock, and put upon it nearly a quart of large maggots (larvæ of *Musca vomitoria*), in order that they might eat away the soft parts. I then placed the crock in a fern-house (that is to say, a miniature green-house) of about thirty cubic feet in dimension, with the view of devoting the maggots (when they were transformed into large blue flesh-flies) as food for some toads (*Bufo vulgaris*) and natter jacks (*Bufo rubeta*) which were confined in the fern-house. I then left them, and on returning six hours afterwards I was astonished at the change which had come on in the verdure of my plants. The flowering fern (*Osmunda regalis*) was turned red-brown; the maiden-hair (*Adiantum Capillus Veneris*) was lying quite flaccid: several species of *Aspidium* and other ferns were as if they had been plunged into boiling water, as was also a bramble (*Rubus corylifolius*), while a wood gourd (*Oxalis acetosella*) was turned yellow, and its leaflets dropped on the slightest touch; in fact, no vegetable in the case escaped destruction of its leaves or fronds. The odour exhaled was not that of putridity, but of that peculiar heavy kind, so characteristic of the marine Mammalia: I do not pretend to speculate on the cause; there did not appear to be any smell of ammonia."

On Natural History as a Branch of Education. By R. Patterson, *F.L.S.*

After a lengthened series of arguments and illustrations, the following conclusions were drawn:—

That the study of Natural History, independent altogether of any physical or pecuniary advantages, is deserving of cultivation, because it is productive of beneficial effects on both the perceptive and reflective faculties; is accompanied by innocent, yet elevated pleasures; and exerts a powerful influence on the moral and devotional character. Hence it was urged that this study should form a *regular* part of the course of education in both schools and colleges; and that naturalists should endeavour to place their favourite science in the same position in these kingdoms which it now justly occupies on the continent.

A comparative View of Animal and Vegetable Physiology. By Mr. Bartlett.

A comparison was drawn between plants and animals in the processes of digestion, circulation, respiration. The necessity was dwelt on of never losing sight of organic media, and the actions they produce, and of an invisible vital principle, which pervades not only every fibre in the muscular or cellular organism, but every atom of each fluid. The fact of the existence of two great antagonizing principles, in the organic and inorganic kingdoms, was pointed out, and their progressive development in the history of the world was shown by means of a diagram. Descriptions were given of the comparative circumstances under which the germs of animal and vegetable life are first developed, the conditions of the embryos, &c. The nerves and sensorial powers of animal tissues, and of their supposed analogies in vegetation, were described. The influence of climate, light, &c. on the vegetable and animal kingdoms was considered, and a contrast drawn between the vegetation of the poles and the equator.

Dr. Lankester exhibited a drawing of a monstrous rose, in which the pistil had become a perfect branch. The drawing was by Mr. Denny of Leeds.

Mr. Littleton of Saltash exhibited a common pear, in which a smaller pear had grown from its apex.

Mr. Derry exhibited some vegetable monstrosities.

Dr. Daubeny exhibited to the Section a portable botanical press, which, by means of a small windlass, was capable of producing a great amount of pressure.

Mr. Prideaux exhibited specimens of copper from the bottom of a vessel which had been acted on by sea-water, and was marked on its surface with small semicircular spots, which in many places penetrated through the copper. He wished to know if zoologists were acquainted with any animal that would produce this effect.

MEDICAL SCIENCE.

Observations on a Pustular disease hitherto undescribed by writers on Diseases of the Skin. By Dr. A. T. Thomson.

From its resemblance to the genus *Porrigo*, the disease was named by the author *Porrigo rodens*. The eruption, unpreceded by any marked derangement of habit, appears first upon the cheeks, in the form of a small group of minute red papillæ, seated upon an inflamed spot; similar groups may appear at the same time on the neck or the upper part of the chest; these soon become pustules, out of which oozes a fluid, which dries into crusts that extend, assuming an irregular circular shape. As the groups of pustules spread, the crusts of those first formed drop off, and leave the cuticle marked with depressions similar to those produced by confluent small-pox. After the continuance of the disease for some time, febrile disturbance shows itself, and a chronic spreading inflammation of the surface ensues. Dr. Thomson considers the exterior or reticular layer of the cutis to be the seat of the disease. The diagnosis, requisite to distinguish it from other species of *Porrigo*, and other pustular diseases, was minutely given, and a case detailed exhibiting the author's mode of treatment. The principal remedies were bleeding and alteratives, particularly the iodides of arsenic and of mercury, in minute doses, with the liquor potassæ and the iodide of potassium in sarsaparilla decoction. The frequent use of the tepid bath, with milk and farinaceous diet, were found useful until the termination of the disease, when more generous food and tonics, particularly the syrup of the iodide of iron, and the solution of the chloride of calcium in the decoction of sarsaparilla, were required. As topical remedies, none were found useful but the tepid bath, and a strong solution of nitrate of silver pencilled over the affected parts. The description was illustrated by drawings representing the disease in its aggravated form, and also in progress of decay from appropriate treatment.

Abstract of a paper on the value of Opium as a remedy in Rheumatism, and on the circumstances which should regulate its employment. By THEOPHILUS THOMPSON, *M.D.*

One of the most remarkable instances of the successive over-valuation and unreasonable disuse of a remedy is exhibited by the history of opium used for the cure of rheumatism. Nearly forty years since, Dr. De la Roche, a London physician, was accustomed to treat the disease with opium in doses of a grain and a half three times a day; at the same time promoting perspiration by warm clothing, and the use of beef tea as diet. The practice, as recommended by De la Roche in the 'Edinburgh Medical and Surgical Journal,' was to some extent imitated, but not generally adopted, and it soon fell into disuse. Recently, however, the practice has been revived by some of the American physicians, and Dr. Corrigan of Dublin has published accounts of cases in which his principal dependence was on this remedy, and in some of which the results were unusually happy. The object of the present communication is to define the conditions in which this powerful remedy is likely to prove efficacious, so as to prevent as far as possible future fluctuations of opinion respecting it, and to guard against its unfortunate misuse or unjust discontinuance. The author of this paper has adopted the opium plan in many cases with very gratifying results. In one instance of severe rheumatic affection of the shoulders and knees, associated with valvular disease and enlargement of the heart and with gastric inflammation, after the relief of the gastric symptoms, a grain of opium was administered every two hours. The pain was speedily relieved, and after twenty pills had been taken entirely removed; in seven days from the commencement of the treatment the patient walked about the room seeming well, and the peculiar barking which had attended the first sound of the heart had become indistinct.

An artist who had long been subject to severe rheumatism, and whose constitution had been repeatedly shaken by prolonged treatment conducted on the usual plan, was attacked with a violent rheumatic affection of the knees and arms. A single small dose of colchicum wine produced great sickness and depression. He was immediately put on the opium treatment, and his own report five days afterwards was as follows:—"I have followed up the pills, and with this result, that I am free from pain and much stronger, and I am sure this is an excellent way of subduing the disease."

A young medical practitioner, who had suffered for months from rheumatism of the back and limbs, against which the whole artillery of anti-rheumatic remedies had been directed, with no other effect than that of leaving him pallid, weak, desponding, anxious, and with a threatened affection of the heart, willingly adopted the opium treatment, in doses of a grain and a half every two hours. He took seventy pills in four days, and in seven days was able to visit his patients.

In most of the rheumatic cases in which full doses of opium have been given, the skin has perspired profusely, the quantity of lithates in the urine has been considerable, and the bowels have not been constipated: the relief has been more prompt and complete than that experienced from the common modes of management, and the strength has been rather improved than deteriorated under the treatment. On the whole I feel justified in adopting the remark of the practical and accurate Heberden: "Præterea meo judicio opium non tantummodo importuni mali præsidium est, sed multum confert ad ipsum morbum tollendum."

The following considerations may assist in determining the limits within which these favourable results may be expected.

The pains of rheumatism generally precede pyrexia, as well as the local redness and swelling, and the fever is in the first instance rather neuralgic than inflammatory. At the onset of such attacks, opium alone might be adequate to effect a cure. In a short time, however, the fever often assumes somewhat of an inflammatory character, and we cannot judiciously dispense with bleeding. In this country there is also for the most part another complication, namely, disordered digestive organs with hepatic congestion, rendering the use of a small quantity of mercury expedient, and in every instance it is important to promote perspiration by suitable clothing and diet. In the neglect of such precautions, opium may aggravate the disease and fall into discredit. When, however, they are observed, and the pulse is sufficiently reduced, the remedy, when freely administered, exhibits peculiar efficacy, and removes the pretext for renewed bleeding, which reaction might otherwise tempt the practitioner to employ, at the risk of aggravating irritation, augmenting the susceptibility of the pericardium to the action of the heart, increasing the tendency to metastasis, and shaking the constitutional strength.

The remedy under consideration appears peculiarly adapted to rheumatic patients in whom the neuralgic element of the disorder is more marked than the dyspeptic or inflammatory. Pain indeed, if not in most instances the most prominent symptom at the commencement of the attack, usually becomes so after the removal of complications by appropriate treatment, and the virtues of opium are signally manifest in those cases in which a slightly soft and bounding character of pulse has been produced by bleeding. The writer offers these recommendations with hope and yet with diffidence, knowing how much time and care are necessary, especially in medicine, to establish a single truth, and how great is the liability to error, even when we seem to follow experience as our guide.

General Observations on the Pathology and Cure of Squinting. By JOHN BUTTER, *M.D., F.R.S., F.L.S., &c., Physician to the Plymouth Royal Eye Infirmary.*

The author in this paper pointed out the different kinds of squinting, their causes, and treatment. He thought that the term "Congenital" was often misapplied to squinting, which he considered to arise generally some time after birth, owing to a contraction of the muscle or tendon produced by some internal disease, as fits, worms, measles, small-pox, hydrocephalus. The real nature of squint he ascribed to an hypertrophy or too great strength of one muscle, or to an atrophy or weakness of the antagonist; and drew an analogy between this and other muscular affections, as hemiplegia, St. Vitus's dance, locked-jaw, and the like.

Remedies have been devised in all ages in vain by philosophers, poets, physicians, and mechanics. Some proposed mirrors, reading small print, masks, spectacles, goggles, gnomons, plaisters, funnels, a candle behind the back, bandaging one eye, and even internal medicines. Suffice it to say that there was no remedy known to the close of the year 1839.

The year 1840 shed a new light on this subject. A cure now is almost certain from an operation. Dr. Stromeyer of Hanover, and Dr. Dieffenbach of Berlin led the way. Their examples were soon followed by Mr. Bennett Lucas of London, and also by Dr. Franz, Mr. Guthrie, and others.

The author considered that during the last year (1840) some thousands of squinters were cured perfectly in the United Kingdom, and many hundreds in the three towns of Plymouth, Stonehouse, and Devonport, of whom a great number had been operated on at the Plymouth Royal Eye Infirmary. He considered the operation simple, safe and successful in skilful hands, and had never known an untoward result or loss of vision from it in his own practice, which appeared, from the living instances of patients cured and shown at the meeting, to have been considerable.

Dr. Butter has discarded the tribe of instruments recommended by others, and performs the operation with only two, *one held in each hand*, viz. forceps with blunt hook appended, and scissors [*].

He gave full credit to the Germans for their inventions, and spoke highly of their medical and surgical attainments. He also briefly alluded to Mr. Tyrrell's most excellent work on the Eye, and considered it very unfortunate for the author that this discovery should have been coeval with his book, which *brings our knowledge of ophthalmic diseases well up to the present period*, but does " not recommend surgical interference in such cases " as squinting. The only wonder is, why this simple operation, which requires about one minute in performing, should not have been sooner discovered. On the whole, the author considered it to be the most satisfactory and successful of all operations which he ever performed or witnessed.

Facts as yet unnoticed in the Treating of Squinting. By J. V. SOLOMON.

The author related certain facts on this subject which had come within his observations.

Observations on two new Fasciæ connected with the Muscles of the Human Eye.
By P. BENNETT LUCAS.

In a treatise on the cure of strabismus by operation, published a year and a half ago by the author of this communication, a description of these fasciæ was given. Mr. Bennett Lucas's present object is to place on the records of the British Association the existence of these new structures; and to inquire into their physiological uses and vital properties,—" points," as the author remarked, " of great moment, as bearing on the actions of a group of muscles which has at all times been looked upon with the liveliest interest by the physiologist, and which now possesses additional importance on account of the new operation for the cure of strabismus." From the positions which these fasciæ hold to the conjunctiva and the muscles of the eye, the author designated them by the names of "*sub-conjunctival*" and "*sub-muscular*"; and having demonstrated their existence by preparations of the human eye, to the satisfaction of the Medical Section, he next proceeded to explain their uses, and to inquire into their practical bearings on the cure of strabismus by operation. On the first of these points Mr. Bennett Lucas observed, that the sub-conjunctival fascia, like the sub-cutaneous fasciæ of the neck, the groin, and other regions, presented many degrees of density in the different subjects in which it was examined. That it was present in all subjects and at all ages, but that in the young subject it was very delicate. That it was composed of condensed cellular tissue, and possessed elasticity; and that its use was to keep in an expanded condition, and to support the long and delicate muscles destined for producing the motions of the eye-ball; without which provision the eye-ball would be abruptly pulled about in its orbit, and that steady, uniform, delicate and perfect movement which it enjoys would be impossible. Amongst the instances of other delicate muscles being similarly disposed as to fasciæ, the author mentioned the omo-hyoid, the sterno- and thyro-hyoid, the sartorius, &c. In operating for the cure of strabismus, when the sections of the tunica conjunctiva and the sub-conjunctival fascia are made, the author remarked, that one might be confounded with the other, on account of both retracting to the same extent on being divided, and presenting almost identical appearances; but that, in order to distinguish one from the other, the test of their different degrees of sensibility sufficed, the conjunctiva being exquisitely sensible when grasped in a pair of forceps, and the sub-conjunctival fascia being perfectly insensible when thus treated,—points of practical importance, as it is injurious to remove any portion of the tunica conjunctiva in the operation for strabismus, whilst it is often necessary to remove portions of the sub-conjunctival fascia.

The sub-muscular fascia was demonstrated as highly elastic, and attached to the neurilema of the optic nerve behind, and to the sclerotica, at the points of insertion of the recti muscles, in front; and that it also was in intimate connexion with the muscles of the eye, at the very situations where the section of them was made in operating for the cure of strabismus.

Observations on Asthma. By Mr. RUMBALL.

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[*] Invented by himself, and made by Mr. Smith, in the Borough.

Some Observations on a Case of Deafness, Dumbness, and Blindness, with Remarks on the Muscular Sense. By Dr. FOWLER.

The case was that of a young woman in the Rotherhithe Workhouse; she was born deaf and dumb, and was blinded by small-pox when three years old. She is now about twenty, and does not hear the loudest efforts of the voice, but starts on a poker held by a string against her ear being struck against a grate, or when her nurse stamps on the boarded floor. Touch was the only sense which others used for communicating with her, or she employed in examining persons or objects. She possessed both taste and smell, but did not appear to have used them. Until the age of fourteen or fifteen her existence appeared merely animal, but then a marked difference took place in her habits; she became as attentive to dress and personal decorum as any other girl. She feels her way without a guide to every part of the workhouse, recognizes all its inmates by the feel of their hands, makes her bed, and sews, not only plain work, but even the more intricate parts of dress. She is very tenacious of what she deems her own, and was much pleased with a shilling which was put into her hands, smiling, curtseying, and feeling it eagerly for some time afterwards. The author deems the true key to so much and minute information derived from touch alone to be the development of *the muscular sense,* and of the reciprocal influence of the adjustments of the different organs of sense on each other, by which all the exquisite attainments of the artisan, the musician, the sculptor, the painter, and even the orator are regulated. Several instances were given of the existence of this sense in the lower animals, and practical suggestions made for its application in educating the deaf and dumb, particularly when these defects are complicated with blindness.

Abstracts of an extraordinary case of Albuminous Ascites, with Hydatids; of five cases of Hepatic Abscess, and of two cases of Phthisis. By Sir D. J. H. DICKSON, *M.D., F.R.S.E., F.L.S., Inspector of Hospitals, and of the African Institute of Paris.*

J. Prendergast, æt. 46, who had been invalided from this hospital two years previously, and subsequently in Haslar with ascites, was re-admitted, greatly emaciated, and with the abdomen enormously enlarged, on the 11th of September last. The dyspnœa and oppression were so great, that, though with little hope of benefit, it was deemed advisable to attempt to relieve him by tapping, on the 17th, but about a pint only of a yellow, gelatinous looking fluid, slowly escaped through the round canula, and he died on the 27th of September, 1841.—*Sectio Cadaveris,* thirty-one hours *post mortem.* The abdomen was much distended by a clear semi-concrete matter, nearly resembling half-liquefied calves-foot jelly, while a thinner effusion occupied the interstices between the intestines and viscera, which had been inseparably accreted by pre-existing inflammation of the peritoneal coat. A great quantity of this matter covered the peritoneum, and adhering to its processes, was detached in filmy vesicular masses, and also nearly filled the cavity of the pelvis. Other globular bodies, more distinctly invested by a fine, pellucid membrane, accurately resembled hydatids; some of them being smaller, were appended to larger ones, which were attached by pedicles to the peritoneal surface of different organs, or in firmer cysts were imbedded in their structure, especially in the spleen: these vesicular cysts were of various sizes, from a small grape or nut to that of an orange, but they decreased in distinctness of organization as they increased in size. The more fluid portion of this jelly-like effusion, coagulated by heat, and on being tested by the nitric acid and acetic acids and tincture of galls, &c., was found to consist chiefly of albumen with a smaller proportion of gelatin.

Sir David Dickson subsequently communicated abstracts of five cases of hepatic abscess, the contents of two of which made their way through the diaphragm and were discharged by expectoration; one, by opening it externally, and another into the cavity of the abdomen. These cases were accompanied by some remarks on the infrequency of serious organic diseases of the liver, which, though at variance with the very generally received opinion, are corroborated by extensive necroscopic investigations during seventeen years at Plymouth Hospital.

In a concluding paper he adduced two cases of phthisis, one of which terminated in hydrocephalus, and both were remarkable for the universality or extension of disease to almost every important organ of the body.

[The following are the titles of cases communicated to the Glasgow Meeting of the Association, by Sir D. Dickson, abstracts of which were not transmitted in time to be inserted in the last volume of Transactions, viz.

" Case of a fatal wound of the intestine, accidentally inflicted by the opening of a clasp-knife during gyration; of marked and rapid pericarditis and pleuritis: and also two very remarkable cases—the one of jaundice from occlusion of the ducts, with distention of the gall-bladder, by a colourless fluid destitute of bile; the other, of ulceration of the right and total disappearance of the left kidney; intended to illustrate the conservative efforts of nature to avert danger by means of compensating organs and vicarious functions."]

On Empyema. By Dr. MACGOWAN *of Exeter.*

The case was successfully treated by the operation of paracentesis thoracis. But as the secretion of pus still continued it became necessary to repeat the operation, and finally to keep a silver canula in the opening, to procure an easy discharge.

Case of Empyema. By WILLIAM JOSEPH SQUARE.

E. C., sempstress, æt. 27 years.—The peculiar features of interest in this case were the development of empyema, with copious expectoration of pink fœtid pus, the formation of external abscess, discharge of the pus contained within the cavity of the pleura, immediate cessation of the peculiar expectoration, and the eventual recovery of the patient. The physical signs of the disease before the evacuation of the matter were the ordinary ones of empyema, conjoined with gargouillement, pectoriloquy, and cavernous respiration under the clavicle of the diseased side; these, the physical signs of a cavity, ceased after the evacuation of the pus, and immediately on such evacuation, metallic tinkling was developed.

The therapeutic operations of nature were principally relied on, in conducting the case to a favourable termination.

On the Ventilation of Ships. By Dr. D. B. REID.

STATISTICS.

On the Statistics of Plymouth, Stonehouse, and Devonport. By H. WOOLLCOMBE, *F.S.A.*

Though some Roman and British coins have been found in the vicinity, there are no traces of the existence of any Roman settlement, or of any town, here or in the immediate neighbourhood, in the Anglo-Saxon times; in Domesday Book, Sutton, the ancient name of the township, appears to have been tenanted only by serfs and fishermen. In the reign of Henry I. a part of Sutton was granted to the Valletort family, and bore their name, in order to distinguish it from Sutton Prior, which was granted to the monks of Plympton. It soon became known as a naval port, for a fleet of 325 vessels assembled in its waters in the reign of Edward I. under the command of Edmund Earl of Lancaster. In the 26th of Edward I. deputies were sent from the town to Parliament. The name of the place was changed to Plymouth about the reign of Edward III. In 1346 it sent a quota of 26 ships and 613 men to the blockade of Calais, but having been subsequently burned by the French, it was so reduced, that in 1414 it did not send representatives to Parliament, though members were returned by Totness, Plympton, Exeter, and Dartmouth. The population of Plymouth, in the last year of Edward III., is stated at 7000 in the record of the poll-tax levied by that sovereign. In 1439 the borough was incorporated by Henry VI., and has ever since ranked as a corporate town. The corporation early paid attention to the instruction of youth, for there is a record, in 1501, of their having engaged a master at a salary of 10*l.* per annum, to teach grammar to the children of the town. In the reign of Elizabeth, the fleet destined to oppose the Armada was assembled in the port of Plymouth. Some of the most distinguished captains were natives of the town or its neighbourhood. Under the auspices of Sir F. Drake, but at the expense of the corporation, the river Mew was brought twenty-five miles from Dartmoor, and from this source the town still continues to receive an abundant supply of fresh water. The increasing prosperity of the town was proved by the formation of the Plymouth Company for colonizing North America, in union with the London Company. It was under their auspices that New Plymouth, U.S., was founded. In 1577 the merchants of Plymouth engaged in the slave trade, as records still exist of their having in that year chartered several vessels to Guinea. The great civil war was injurious to its prosperity; the people of Plymouth embraced the popular side, while the gentry of the neighbourhood were decided royalists. To punish the townsmen, and to check their republican propensities, Charles II. erected a citadel. Some of the regicides were imprisoned on St. Nicholas Island, where, according to tradition, they were treated with great severity. In the reign of William III. the naval advantages of Plymouth, which had been noticed by Sir Walter Raleigh a century before, were first appreciated by the government. A dockyard, victualling office, gun wharf, and hospital, were erected, which laid the foundation of the present town of Devonport. In the same year, 1696, the first lighthouse was constructed on the Eddystone. Mr. Woollcombe then detailed the history of the several lighthouses built upon this rock. In 1812 the Breakwater was commenced, but Mr. Woollcombe stated that fears were entertained that this structure would eventually injure the anchorage ground. The population of Plymouth had increased from 20,000 in 1812, to 31,000 in 1831, and to 36,000 according to the present census. The houses are better built than formerly, the appearances of domestic comfort more striking, and the literary and charitable institutions greatly multiplied. The returns of the Custom-house for the last official year amounted to 135,930*l.* 15*s.* 7*d.* Stonehouse has risen from a population of 3667, in 1801, to nearly 10,000 at the present time; while Devonport, which could scarcely be said to exist at the beginning of the century, now contains 34,000 souls. The chief wants of Plymouth and Devonport were church accommodation for the poor, and education. The author's returns on both subjects were incomplete, but it appeared that there are five churches in Plymouth, two in Stonehouse, and four in Devonport. There are eighteen dissenting chapels and one Jewish synagogue in Plymouth, but the numbers for Stonehouse and Devonport had not been ascertained. There is only one Roman Catholic place of worship in the district, the chapel at Stonehouse. The education returns were confined to the higher classes of schools, and, therefore, are no test of the intellectual condition of the community. Mr. Woollcombe added a rough estimate of the government expenditure, from which it appeared that 2300*l.* are paid every Friday night in wages to the naval operatives. He had not procured the Ordnance returns.

Statistical Report of Patients of the Plymouth Public Dispensary, during the years 1838, 1839, *and* 1840. *By* SAMUEL DERRY, *Surgeon.*

The author presented a series of Tables of the number of cases of each disease, and the relative number of males and females affected; the number of deaths, the relative number of males and females who died, and their ages at the time of death.

On the Agricultural Products of Cornwall. By Sir C. LEMON, *Bart.*

This paper had been commenced some years ago, but on account of unexpected difficulties it was laid aside for a time; but reflecting that many statistical records which have little value at the present day may in a future age possess importance, the author resumed his labours. Cornwall being nearly surrounded by sea, he hoped to have been able, for a series of years, to compare the progress of population with the imports of grain and corn, but he found that the books at the Custom-house in Falmouth had been destroyed, by order of the Government, fourteen years ago, and nothing preserved but a few extracts, which were of no value in the present inquiry. From the various records and itineraries of Cornwall it appeared, that down to the date of Fraser's Agricultural Report in 1794, the agriculture of the county was neither deficient nor redundant, but nearly sustained the population. He read extracts from Leland's journey in the reign of Henry VIII.; from Carew, who states that in abundant seasons the county produced a surplus of corn for exportation; from Camden and Norden, who mention that corn is produced in competent abundance. Blome, who wrote in the reign of Charles II., states that the county was more inclined to sterility than fertility, but that the manuring of the ground with sand enabled the industrious to raise good corn. Borlase, who wrote in 1756, asserts that agriculture had not increased in proportion to the population, and that the county was beginning to import corn. Fraser, who wrote in 1794, complains that agriculture was neglected, and that, if more attention were paid to it, the county would support more than its existing population. Mr. Morgan, in 1808, describes agriculture as having greatly improved since Fraser's time. The number of inhabitants in successive ages can scarcely be obtained. Lysons refers to a poll-tax in the reign of Edward III. (1377), and thence calculates the population of the county at 34,960 persons. The number in 1700 is stated by Marshall at 105,800. From Finlaison's returns Sir C. Lemon calculated, that in 1760 the number was 137,000. By the census of 1801 the population was 188,269. And from these data was framed a table of the population which probably was fed by the agriculture of the county, previous to 1794,

Years.	Population.	Increase per cent. of agricultural produce.
1683	69,900	
1691 1733	105,800	51
1756	135,000	28
1794	171,000	26⅛

The whole period 144 per cent.

Such appears to have been the progress of agriculture during the 200 years previous to Fraser's report. The present population is about 345,000, dependent on agriculture, fisheries, and corn imported by the coasting trade for subsistence. From the returns collected it appears that there is an annual deficiency of grain equal in effect to 52,786 quarters of wheat. Against this is to be set an export of 11,690 cwt. of potatoes, valued at 5845*l*., and equivalent to 2050 quarters of wheat at 57*s*. per quarter. No accurate information could be obtained respecting the cattle which cross the borders to and from Devonshire, but from a comparison of various accounts, the following may be taken as an approximation to their amount and value:—

Exported.—Lean cattle, 3500, at 10*l*. per head		£35,000
	Cattle for the butcher, 1200, at 15*l*. per head	18,000
		53,000
Imported.—Cows, &c. fat, 900, at 12*l*. per head		10,800
		£42,200

This balance also should be carried to the credit of the agriculture of the county, and is equal in value to 14,807 quarters of wheat at 57*s*.

The supplies to the shipping may be worth 5000 quarters more; the whole together making a set off of 21,857 quarters of wheat to be deducted from the deficiency stated above, and leaving finally a deficiency of agricultural produce necessary for the consumption of the county, equal to 30,929 quarters of wheat. The value of this quantity in money is about 88,147*l*.; and this sum must be annually expended out of the other exports of the county to the parties supplying it with corn. These exports may be estimated as follows:—

Copper ore, averages of 1838 and 1839	£862,527
Tin sold by ticketings	215,895
Do. by private contract	71,965
Lead	13,680
Silver	14,777
Iron	16,108
Arsenic	2,834
Granite	8,667
China-clay	35,160
Sulphur, slate, &c., no return.	
Pilchards and other fish	28,385

making in round numbers about 1,300,000*l.* annually, and showing that about $\frac{1}{17}$th of the annual exports covers the deficiency of agricultural produce. The consumption of cattle and sheep in the county, estimated from the hides supplied to the tan-yards, is,

Bullocks	15,950
Calves	11,550
Sheep	56,600

Computing the carcase of each bullock at 6 cwt. each, each calf at 1 cwt., and each sheep at $\frac{1}{2}$ cwt., the gross amount will be 135,500 cwt., equal to about 45 lbs. for each person of a population of 336,000 souls. This is exclusive of pig-meat, the consumption of which cannot be ascertained, but is certainly great. It is estimated that there are in Cornwall,

Of cultivated land	550,000 acres.
Of improvable land	190,000 ...
Of unprofitable land	109,000 ...

To ascertain the qualities of the soil, Sir C. Lemon had specimens analysed of the natural soil taken from the three principal geological formations, viz. the slate, the serpentine, and the granite. This analysis gave very unexpected results. There was an extraordinary similarity between the ingredients and the proportions in all these specimens, and what was still more surprising, a total absence of some of the characteristics of the rocks beneath. The feldspar in granite contains about 17 per cent. of potash, but there is no potash in the soil above. The serpentine contains from 30 to 40 per cent. of magnesia, but there is no magnesia in the soil of Goonhely Downs. Yet these are indestructible substances, and if the soil had been formed by the decomposition of the rocks beneath, a considerable quantity of each must have been present. As these soils are deposited on high grounds, in the case of Goonhely Downs extending over a very large and elevated plateau, Sir Charles concluded by proposing, as a geological problem, "Whence did they come? How formed? or how transported?"

Abstract of a Report on the Condition of the Working Classes in Kingston-upon-Hull.

In the year 1839, the Manchester Statistical Society sent their agent to examine into the condition of the working classes in the town of Hull, and the following are among the more important results elicited by the inquiry:—

Hull affords less employment to women and children, and more variable employment to men, than the manufacturing districts. It also contains a far smaller proportion of immigrants from Wales, Ireland, and Scotland; and a superior state of education, and certain advantages of physical condition, are distinguishing traits of this district. Out of 8757 dwellings, only fifteen were cellars, containing forty-four inhabitants, that is, $\frac{1}{7}$ per cent. of the whole population, or $\frac{1}{5}$ per cent. of the working classes; while in Manchester and Salford, ten per cent., and in Liverpool twenty per cent. live in cellars. The separation of families is also more distinct, and the system of taking lodgers less prevalent; the average of individuals to each separate occupation being 4$\frac{1}{3}$ in Hull, against 5$\frac{1}{7}$ in Pendleton, near Manchester, where a similar inquiry was instituted. The centesimal proportions of the population of Hull, divided according to nativity, are,—

English	95·08 per cent.	Welsh	0·48 per cent.
Irish	2·24 „	Foreigners	0·84 „
Scotch	1·36 „		

Out of 9832 males, only 709 were unemployed; but out of 11,400 females, only 2606 carried on an ostensible trade apart from household occupations. In the remaining 8794 females are not included domestic servants, or those having a definite calling within-doors. It is worthy of remark, that this number of unemployed females coincides almost exactly with that of the heads of families; and hence it may fairly be concluded that in ordinary times there are but few cases in which the labour of adult males is not sufficient to maintain the family in tolerable comfort. The rental of cottages in Hull appears to be very moderate, the average being somewhat under two shillings a week for houses, one shilling and five pence for chambers, and one shilling and two pence for cellars; an average applicable to rather more than half the residences of the working classes. The state of drainage and the supply of water to the houses are points very difficult to ascertain, but so far as information could be procured, Hull may be considered as favourably circumstanced in both respects.

Drainage.		Water.	
With adequate drainage	4116	With an ample supply	4957
Inadequate	671	Inadequate	209
No drainage	299	No supply	107
Not ascertained	3671	Not ascertained	3484
Total	8757	Total	8757

The dwellings in Hull have a decided advantage over those in the manufacturing districts; the rents are lower, the streets cleaner, the houses better ventilated, and less frequently situated in courts.

Number and Condition of Dwellings.

Dwellings.	Respectable.	Comfortable.	Middling.	Uncomfortable.	Not ascertained.	Total.
Houses ...	2809	1439	448	1181	362	8239
Chambers	91	547	673	869	323	2503
Cellars ...	0	0	10	5	0	15
Total...	2900	1986	1131	2055	685	8757

From this table it appears that two-fifths of the houses of the working classes are comfortable, one-fifth middling, and two-fifths uncomfortable. The following is the return respecting cleanliness:—

Dwellings.	Respectable.	Clean.	Middling.	Dirty.	Not ascertained.	Total.
Houses	2809	1639	915	A 430	446	6239
Chambers.......	91	898	735	B 534	245	2503
Cellars	0	7	6	2	0	15
Total.........	2900	2544	1656	966	691	8757

The supply of beds in each house, compared with the number of its inmates, was one point to which the attention of the agent was particularly directed, and the result was far from satisfactory. Out of 3964 dwellings from which information was procured, there were 475 with only one bed for the accommodation of five persons and upwards, 103 of these having from seven to eleven persons in one bed. All comment on such a state of things would be superfluous; its existence is not willingly acknowledged by the people themselves, and the information can scarcely be elicited by direct inquiries.

The majority of the benefit societies in Hull are not enrolled under the Act, and consequently afford little security to the subscribers, even when the principles on which they are based do not happen to be unsound. 1615 heads of families are enrolled in benefit societies, 3496 are *not*, and 3646 have not been ascertained. The last head of inquiry related to the extent to which books were possessed by the people.

Dwellings.	Houses.	Chambers.	Cellars.	Total.
Possessing books	2253	1294	8	3555
—— a Bible only	34	39	0	73
—— a Testament	42	33	2	77
—— no books ...	484	734	5	1223
Not ascertained	3426	403	0	3829 A
Total......	6239	2503	15	8757

Of the 3829 A in the last column, 2900 belong to the superior class, and may therefore be fairly presumed to possess books. The greater part of the remaining 929 had one or more religious tracts, which they were in the habit of receiving from visitors who called and exchanged them periodically.

On the Economic Statistics of Sheffield. By a COMMITTEE.

Sheffield is known abroad chiefly by its cutlery; but it is not less celebrated at home for its silver and plated productions. Those engaged in the latter species of work have not been subject to the same vicissitudes as the cutlers, but have been constantly in full work, and receiving high wages. The following table shows the value of British-made plate for a series of years. It must be borne in mind that the goods are generally of an inferior quality:—

1829	£177,830	1833	£179,283
1830	190,515	1834	192,269
1831	188,144	1835	231,903
1832	173,593		

The annual consumption of these goods in England is estimated at 1,200,000*l.* The earnings of the men vary, in proportion to their skill, from 18*s.* to 42*s.* per week, and some receive much more. The unions among the workmen are rich, and should any master resist their dictation, they can afford a handsome allowance weekly; but the restrictions imposed by these unions are not so severe as in other trades, partly on account of the variety of work, and partly on account of the superior intelligence of the workmen. The number of operatives is a little over 400. They have sick societies, separate from the unions, which afford efficient relief to those who have been incapable of working for three successive months.

The saw-manufacture is next in importance. The workmen are remarkable for sobriety, intelligence, and good conduct. They have unions, which regulate wages, the number of apprentices, and afford relief in sickness. There are 208 journeymen, about twenty of whom are not in union; the number of boys is 130, which exceeds what is allowed by the rules of the trade. The wages vary according to work and skill, but may be stated at from 24*s.* to 32*s.* per week. Piece-work is still more uncertain, ranging from 28*s.* to 45*s.* Wages are about the same now as in 1814, but work has been increased 25 per cent. The trade depends on foreign orders, and is subject to great fluctuations. The edge-tool manufactory employs about 200 foremen, 200 strikers, and 50 apprentices. The average of the wages, supposing a man to work eleven hours per day, is, foreman 34*s.*, and strikers 22*s.*: they all work by the piece. The labour is severe, and produces exhaustion, which leads to vicious excesses and intoxication. The spring-knife manufacturers are among the worst paid in the town, and suffer more than any others in seasons of commercial distress. Their numbers are—

Spring-knife hafters	1400
Scale and spring forgers	150
Blade-forgers	300
Pocket-blade grinders	100
Pen-blade grinders	300
Apprentices	600
Total	2800

In the first manufactories of the town, the average of wages is from 16*s.* to 25*s.* per week; but in many inferior manufactories they receive only from 12*s.* to 16*s.* The tools required by these men are few and simple; and hence, in periods of distress, they manufacture for themselves, and sell the goods to hardware dealers, &c., which produces still greater depression in the trade. These operatives marry early, and have generally large families.

The file-trade employs 1420 men, 700 boys, and 100 women: the wages vary considerably, as the work is paid by the piece; but the following is the average:—

	£	*s.*	*d.*
Forgers—Double-hand, average	2	19	7*
Single-hand	1	11	10
Saw-file	1	3	7

* Foreman, 1*l.* 12*s.* 10*d.*; Striker, 1*l.* 6*s.* 9*d.*

File-cutters—A man, average	1	2	6
A man and boy	1	11	8
A man and two boys	2	0	6
A grinder	1	14	0
Ditto, with a boy	2	7	4
Scourer (a woman)	0	9	0

The filers are inferior to the platers, but are superior to the grinders, &c. The number of clubs among the operatives in Sheffield is 56. The numbers in 1839 only amount to 7978; and the whole stock, belonging to 38 clubs, is 53,373*l*. There are no accounts of the numbers in 17 clubs, and of the funds in 18. The number of secret orders is 36, containing 2940 members.

On the Vital Statistics of Sheffield, prepared by a local Committee, and forwarded to the Section by Dr. HOLLAND.

It began by describing the position of the town, showing how favourably it was circumstanced in respect to ventilation, drainage, and supply of water. It had advanced very rapidly both in population and wealth; but though no data existed for determining the latter, it was believed that wealth had advanced in the greater ratio. Sheffield did not possess many large capitalists; the nature of the trades followed in the town did not require any expensive outlay in stock and machinery. A remarkable proof of its advancement was, that in the middle of the last century there was only one commercial traveller employed in the town; there is now scarcely an establishment that does not employ one or more. The following table shows the increase of population:—

In 1736	16,000.		
1801	31,000,	an increase of	2 per cent. per annum.
1811	53,000	———	1½ per cent.
1821	65,000	———	2 per cent.
1831	91,000	———	3½ per cent.
1841	117,000	———	2¼ per cent.

The value of property in Sheffield had been greatly diminished by the cessation of foreign demand; and this had principally affected the cutlers, who depend on the export trade, but had not seriously injured the silversmiths and platers, who look to the home market. In no place perhaps have the poor-rates exhibited such extraordinary variations. In 1801 they were 7200*l*.; but in 1820 they rose to 23,000*l*., out of a rental which, it is supposed, did not exceed 46,000*l*. In 1825 they were reduced to 6000*l*.; in 1836, to 5000*l*.; and in 1837, to 4000*l*. The present amount is 6500*l*.; and the distress at the present moment is believed to be greater than it has ever been before. Trades in which combinations and associations exist, are found to become claimants on charity less frequently than those which are uncombined. This is attributed by the author of the Report to the habits of foresight and prudence which arise from trade societies for a common object. One branch of trade, within the last four years, paid to unemployed workmen in the same line not less than 2000*l*. The author of the Report then entered into a comparison of the condition of the operatives in Sheffield with those of Liverpool, Leeds, and Manchester, for the purpose of showing that enormous capitals are not favourable to the happiness of the general body; and that the greatest misery must be expected in the vicinity of the greatest wealth. He dwelt particularly on the fact, that the operatives of Sheffield usually have a house to themselves; and that there is nothing in that town similar to the cellars of Liverpool, or the lodgings of Manchester. The danger to life involved in the manufactures at Sheffield, was illustrated by a comparison of the numbers who die beyond the age of 70 in that town and in other districts.

Out of every 1000 deaths the average above 70 is 145 for England and Wales.
210 for the Northern and Western Ridings of Yorkshire.
104 for London.
66 for Sheffield.
63 for Liverpool and Manchester.

The mortality of infants under 7 years of age, in every 1000,—
270 for the mining districts of Staffordshire.
180 in the agricultural counties.
242 in Sheffield.

In comparing the mortalities of different trades, the two classes of occupation most unfavourable to human life, are found to be those which require frequent transitions from heat to cold, and which generate metallic dust. In what is called "dry grinding," the mortality is said to be "truly appalling;" but the rate was not stated, save that a "dry grinder" is considered an old man at 35. Early marriages in Sheffield are more common among the underpaid than among the higher classes of workmen; and the ratio of children to a marriage is also higher in the more distressed class. But Sheffield exhibits a less ratio of marriage than most other manufacturing towns. In Sheffield (1839–40) the proportion of marriages to a thousand inhabitants was 9¼, while in Leeds it was 17. The writer of the Report then entered at great length into the question of Savings Banks, for the purpose of showing that the amount of deposits affords no trustworthy criterion of the prosperity or adversity of a community. He stated that adversity, by forcing prudential considerations on the mind, was more likely to make men become depositors than prosperity. As an example, he stated, that during the last three years trade had notoriously declined in Sheffield, and had gone on in a falling ratio, yet the amount in the savings banks had been on the increase.

In 1838 there were	4093	depositors to the amount of	£142,000
1839 „ „	5088	„ „ „	143,000
1840 „ „	5248	„ „ „	148,000

The proportion of artisans among the depositors appears to be very small; and it is least among those to whom a provision is most necessary. Out of 5000 cutlers there were only 221 depositors; while out of 450 silversmiths and platers, there are 89. The greatest number of depositors is found in the present year, which is the year of greatest depression.

Mr. Fripp read a paper on the Statistics of Education in the city of Bristol, which was intended to complete and perfect the Report he had made on the subject at the meeting of the Association in 1836. The present population of the city of Bristol is about 120,000, and this number is assumed as the basis for the proportions between the instructed and the uninstructed. The schools which formed the subject of inquiry are divided into six classes.

Infant schools	14	with	1,705	scholars,	11·60	per cent.
Dame „	217	„	3,015	„	20·52	„
Common day and evening	219	„	7,900	„	53·77	„
Free and endowed	24	„	1,334	„	9·08	„
Superior	38	„	740	„	5·03	„
Total day schools	512		14,694			
Sunday schools	86		7,171			
Schools	598		21,865			

The total number attending Sunday schools is 11,684, but 4513 also attend day schools, and are therefore not reckoned. It appears that of the total number of children receiving instruction,—
10,181, or about 8½ per cent. of the population, attend day and evening schools.
4,513, or about 3¾ per cent., attend both day and Sunday schools.
7,171, or about 6 per cent., attend Sunday schools only.

Of the total number of children in day and evening schools,—
7,825, or 53¼ per cent., are boys.
6,869, or 46¾ per cent., are girls.

In the Sunday schools there are—
5,780, or 49½ per cent., boys.
5,904, or 50½ per cent., girls.

The following is a comparative statement of the ages of the children attending day and evening schools:—

Under 5 years of age........................	3,274, or 22¼ per cent.
Between 5 and 15	10,730, or 73 per cent.
Above 15	502, or 3½ per cent.
Not ascertained	188, or 1¼ per cent.

The following is the estimated amount of payments in the schools entirely supported by the pupils:—

		Scholars.		Per annum.
	217 dame, containing	3,015	paying	£ 2,390 17 9
	177 common day ...	3,479		10,298 11 8
	14 evening	253		387 10 2
Total	408	6,747		13,076 19 7
	38 superior	740		18,500 0 0
Total	446	7,487		31,576 19 7
In schools assisted by subscription—				
	14 infant, containing	1,705	paying	682 3 6
	28 common and day	4,168		1,831 6 7
	24 free and endowed	1,334		
Total	512	14,694		£34,090 9 8

Reading is taught in 486; writing, in 292; arithmetic, in 250; needlework, in 344; knitting, in 36; grammar, in 196; geography, in 186; history, in 153; drawing, in 45; classics, in 23; mathematics, in 22; music, in 1; domestic duties, in 4; moral duties, in 362; religious duties, in 371; French, in 46; mensuration, in 22; navigation, in 2. Refused information, 23.

Comparative Statement of the Income and Expenditure of certain Families of the Working Classes in Manchester and Dukinfield, during the years 1836 *and* 1841. *By* W. NEILD, *Mayor of Manchester*

The general results are contained in the following tables:—

Income and Expenditure of Twelve Families in Manchester.

No. in family.	Trade.	Income of family per week.		Expenditure in food per week.		Left for instruction and purchase of goods.		Going back in the world per week.	
		1841.	1836.	1841.	1836.	1841.	1836.	1841.	1836.
		l. s. d.		l. s. d.	l. s. d.	l. s. d.	l. s. d.	l. s. d.	l. s. d.
9	Machine Printer	4 7 0	Income the same.	2 15 8	2 6 8	1 11 4	2 0 4		
10	Millwright	4 10 0		2 9 7	2 2 2	2 0 5	2 7 10		
2	Watchman	0 15 2		0 13 4	0 11 9	0 1 10	0 3 5		
8	Stoveman	2 17 0		2 0 1	1 12 2	0 16 11	1 4 10		
2	Washer	0 14 0		0 11 4	0 9 10	0 2 8	0 4 2		
6	Overlooker	1 14 0		1 7 10	1 4 3	0 6 2	0 9 9		
4	Labourer	1 2 0		0 19 1	0 16 9	0 2 11	0 5 3		
4	Labourer	1 1 0		1 1 3	0 18 4		0 2 8	0 0 3	
10	Dyer	2 0 0		1 19 0	1 12 0	0 1 0	0 8 0		
5	Blue-dipper	1 0 0		1 0 8	0 17 9		0 2 3	0 0 8	
7	Watchman	1 1 0		1 1 10	0 19 1		0 1 11	0 0 10	
9	Dyer	1 3 0		1 10 0	1 5 2			0 7 0	0 2 2
	Total.........	22 4 2		17 9 8	14 15 11	5 3 3	7 10 5	0 8 9	0 2 2

Income and Expenditure of Seven Families in Dukinfield.

No. in family.	Trade.	Income of family per week.		Expenditure in food per week.		Left for instruction and purchase of goods.		Going back in the world per week.	
		1841.	1836.	1841.	1836.	1841.	1836.	1841.	1836.
		l. s. d.	l. s. d.	l. s. d.	l. s. d.	l. s. d.	l. s. d.	l. s. d.	
3	Power-loom weaver ...	0 14 4	1 1 6	0 17 4½	0 16 0½		0 5 5½	0 3 0½	
6	Dresser	1 4 0	1 17 0	1 1 1½	0 18 2½	0 2 10½	0 18 9½		
6	Labourer	0 18 8	1 8 0	1 4 3	1 0 11½		0 7 0½	0 5 7	
3	Card-room hand	0 8 8	0 13 0	0 11 4	0 9 9		0 3 3	0 2 8	
5	Spinner	0 14 4	1 1 6	0 19 2	0 16 10		0 4 8	0 4 10	
4	Warehouseman	0 10 8	0 16 0	0 14 6	0 12 9		0 3 3	0 3 10	
7	Assistant Mechanic ...	0 16 0	1 3 0	1 0 4½	0 17 9		0 5 3	0 3 7	
	Total.........	5 6 8	8 0 0	6 8 1½	5 12 3½	0 2 10½	2 7 8½	1 3 7	

Account of the Monts de Piété of Rome, Paris, and other cities on the Continent. *By* HENRY JOHN PORTER, *F.S.S., Tandragee, Ireland.*

The author stated that an institution of the kind had been formed at Rome before the Christian era by the Emperor Augustus, but that they were revived in modern Italy under the patronage of the Popes. The system was supported by the Franciscans, and opposed by the Dominicans, until the matter was set at rest by Leo X., who declared lending-houses to be legal and useful, a decree subsequently confirmed by the Council of Trent. From an old Italian work, entitled 'The Pious Institutions of Rome,' published in 1689, he gave the following account of the origin of the Monte di Pietà. The work was so rare that he could not purchase a copy, but had been permitted to make an extract.

"The original founder of this great work of benevolence in Rome, was Padre Giovanni Calvo, a Franciscan of the order of Minorites, who obtained the sanction of Paul III. for an association of some persons of distinction, whom he had united for this object. This pontiff not only approved the institution of the present sacred Monte di Pietà, but assisted the undertaking with money, enriched it with indulgences and privileges, and conferred on it all the favours enjoyed by similar institutions. The sacred Monte di Pietà has for its object the advance of sums of money, in each case not exceeding thirty crowns, to poor and necessitous persons of every description, on the security of pledges. This is accomplished as individuals, actuated by benevolent motives, supply funds to the institution, or, apprehensive of danger if they retain money at home, deposit it with the establishment for greater security. The pledges which are taken from day to day are retained eighteen months, after which, if the owner fails to claim them, they are sold publicly and fairly, by auction. The proceeds are applied to satisfying the claims of the establishment, including interest at two per cent., and the surplus is returned to the owner of the pledge. The institution is governed by a fraternity, which every year elects forty of its members as directors. The directors meet weekly, to deliberate on all that is required for the maintenance of the establishment, which may be regarded as the common patrimony of the poor, and the great mansion of all." The document then set forth the favours which had been shown to the institution by successive popes, ending with the promulgation of its statutes by Alexander VII. Mr. Porter stated, that as he was anxious to obtain some information respecting the founder of this institution, he applied to the General of the Franciscan order, and obtained from his secretary the following extract from the records of the Franciscan monastery at the Arracœli in Rome:—"1541. John Calvus, son of Calvus, was a native of the kingdom of Corsica, and educated in the province of Corsica. He was a man renowned for his learning, skill, and suavity of manners. He held the office of Commissario in the court of Rome; he was selected at the general assembly at Mantua, to regulate the whole order of Franciscans. He was the first person to institute the Monte di Pietà. He was eminent for a two-fold apostolic office; he was theological advocate at the Council of Trent; he was esteemed by Paul III., and the kings of France and Lusitania. He died at Trent 21st of January 1547, having held office about six years." The following table shows the state of the Monte di Pietà in Rome, for the year 1839:—

1839.	Number of articles.	Amount Lent.					Average amount on each article.	
		Italian money.		English equivalent.				
		Scudi.	Boiocchi.	*l.*	*s.*	*d.*	*s.*	*d.*
Remaining in store, Dec. 31, 1838...	94,872	349,849	90	80,165	11	8		
Pawned in 1839......	306,161	925,327	10	211,554	2	1	14	2⅓
Total...........	401,033	1,275,177		291,719	13	9		
Redeemed	287,234	891,259		203,746	17	1	14	2
Remaining in store, Dec. 31, 1839...	113,799	383,918		87,972	16	8		

Amount of capital in the Monte di Pietà department (in English money)..	£104,360	8	11
Amount in actual circulation, 31st Dec. 1839	87,972	16	8
Balance in hand.................	£16,387	12	3
The greatest amount lent in one sum......................	£2,750	0	0
The least	0	0	10½
Expense of management (98 persons being employed)	6,432	9	7
Net profits	4,761	12	6

The following return shows the state of the Banking department, which was joined to the Monte di Pietà in 1589:—

Total amount lodged in 1839..............................	£438,755	3	4
Amount of drafts in 1839	407,536	15	10
Increase of capital in 1839	£31,218	7	6

The institution is divided into three departments, called Primo Monte, Secondo Monte, and Terzo Monte. The first and second are for the reception of goods on which the amount borrowed does not exceed a scudo (4*s.* 7*d.*); the third is for articles of higher value. The net profits for 1839 do not include a large class of the borrowers, as the institution lends, without interest to the poor, sums not exceeding a scudo; and to this class of borrowers 18,333*l.* 6*s.* 8*d.* was lent in the year 1839. The expense of management does not include pensions which are given to about thirty retired officers, and to the widows and orphans of such as have died in the service of the institution. Officers are obliged to lodge five per cent. of their salaries for a retired fund. After forty years of service they may retire on full pay, and on half pay after twenty years of service. The poor are not the only persons benefited by this institution; merchants, traders, and even crowned heads have taken advantage of it. Among the articles in pawn, Mr. Porter saw a diamond-ring, a suite of pearls, a snuff-box with a likeness of Louis XVIII. set in pearls, a coronation medal, and many similar articles. He had been entrusted with the secret of the ownership, but of course could not betray the confidence reposed in him. Not more than one-tenth of this valuable description of property is ever sold, nine-tenths being the average of the releases from the Terzo Monte. The government of the Monte di Pietà is entrusted to a protector, who is the treasurer of Rome for the time being. Mr Porter gave a brief account of similar institutions at Turin, Leghorn, and Genoa, but entered into more detailed statements respecting the Mont de Piété at Paris. The following table shows its operations for the year 1840:—

Mont de Piété of Paris.—Operations for the year 1840.

Pledging department.	No. of articles.	Amount lent.				Average amount on each article.		
		Francs.	£	s.	d.	£	s.	d.
Pawned	1,220,692	18,576,020	743,046	16	8	0	12	2
Renewed	241,130	5,763,827	230,553	1	8	0	10	9½
Total......	1,461,822	24,339,847	973,593	18	4			
Releasing department.								
Redeemed	1,090,119	16,362,143	654,485	15	0	0	12	0
Renewed	241.130	5,763,827	130,553	1	8	0	10	9½
Sold by auction .	98,178	1,641,575	65,663	0	0	0	13	4¼
Total......	1,425,427	23,757,545	850,701	16	8			

When pawns are renewed, the goods are revalued, and the borrower is compelled to make compensation for their deterioration.

State of the Magazine of Pawned Goods at Paris, 31st December 1840.

	No. of articles.	Value.			
		Francs.	£	s.	d.
Remaining in store, Dec. 31, 1839.	800,347	15,311,359	612,456	7	6
Pawned in 1840	1,461,822	24,339,847	973,593	18	4
Total	2,262,169	39,651,206	1,586,050	5	10
Lent out of store, redeemed, or sold.	1,429,427	23,767,545	850,701	16	8
Remaining in store, Dec. 31, 1840.	832,742	15,883,661	735,348	9	2

Average Daily Transactions.

	Articles.	Amount.			
		Francs.	£	s.	d.
Pledges	3840	59,655	2485	12	6
Renewals	735	17,505	729	7	6
Releases	2830	42,998	1791	11	8

Connected with the Paris Mont de Piété are four depots managed by commissioners, who have a certain profit on every transaction. The importance of such an accommodation appears from the following estimate:—

In every 100 pawns, 9 are by the public, and 91 by commission.
——— 100 renewals, 40 by the public, and 60 by commission.
——— 100 releases, 44 by the public, and 56 by commission.

The interest charged by the Paris Mont de Piété is 9 per cent., and one-half per cent. for valuation. The number of watches in pawn is generally from 250,000 to 300,000. There were over 6000 mattresses in store, and the directors had resolved to admit no more. Mr. Porter concluded by stating, that in 1839 a sum equivalent to 7821*l.* 13*s.* 4*d.* had been given from the Paris Mont de Piété for the support of the hospitals, and expressed his readiness to correspond with any persons interested in such institutions.

On the Loan Funds in Ireland. By HENRY JOHN PORTER, *F.S.S., Tandragee, Ireland.*

The interest excited by the author's paper on Pawnbroking, read at Glagow, induced him to procure a statistical account of the operation of loan funds in Ireland, together with the opinions of the directors as to the benefits conferred, the difficulties to be overcome, and the evils, if any, which may arise from their operation. He presented tables of 215 loan funds, three of which were reported to have ceased operation since the accounts were received. It was necessary, before entering on the subject, to allude to a system which was general in Ireland, and which had only been partially checked by the working of the loan funds. It is explained in the following extract from the Report of the Ballycastle Loan Fund:—"It was a common practice to supply meal at a price one-third above the market. Potatoes were also supplied during the cheap season, an engagement being entered into by the buyer to pay the summer price, whatever it might be; nor was this all, for an interest was charged on the promissory note at the rate of 6 per cent. Again, if a poor man required a cow or a horse, he applied to one of the money-lenders, who either purchased it for him, charging him 1*l.* for the bargain, and sometimes more, or counted down the money asked for by way of tender, and then abstracted 1*l.* for the compliment, in either case putting the borrower to the cost of 1*s.* 6*d.* for the promissory note, and requiring him to pay 6 per cent. interest. In like manner, weavers were obliged either to take yarn from the dealers considerably above the market price, or if, as was often done, they borrowed 20*s.* for one month, or between two markets, to purchase yarn for themselves, they were charged 1*s.* at least, and frequently more, for such accommodation." The funds are raised by deposits, and it is gratifying to find that the sum of 44,811*l*. has been deposited by farmers, as the money-lenders just described were persons holding from twenty to fifty acres of land; the greater part of this sum was therefore formerly employed in usurious practices, to which the farmers now prefer the certainty of 5 or 6 per cent., without any trouble or risk. The sum deposited by manufacturers is trifling, being little more than one-seventh of the agricultural amount. It appears that 329 servants have deposited 7157*l*.; these depositors are not numerous, except in those loan societies where small sums are received at a lesser interest, until they amount to 5*l*., when a debenture may be purchased and the interest increased to 6 per cent. Depositors of 50*l* are the most numerous class; Mr. Porter thinks them desirable only at the commencement of such an institution, and wishes them to be gradually paid off, in order to make room for the depositors of smaller sums. The greatest number of loans have been applied, it is believed, to the most useful purposes. In the year 1840 there were issued—

	Loans.	Amount.
For the purchase of horses, cows, pigs, &c.	37,766	£152,875
For the purchase of seed, manure, implements, &c., and other agricultural purposes	9,247	32,574
Total	47,013	£185,449

For the purchase of provisions the number of loans has been 23,363, amounting to 77,510*l*. Loans for the payment of rent and debts are not generally encouraged; nevertheless, there are many instances of the best effects from both of these objects. For the purpose of dealing in various ways, the sum of 53,938*l*. has been issued, in 14,295 loans. This class of borrowers is very numerous.

The following is a return of the loan funds whose directors have expressed their conviction of the benefits conferred by these institutions in various ways, viz.—

32 Loan funds bear testimony to advantages conferred on farmers in their crops and tillage.
52 „ „ to small farmers in the purchase of cattle.
64 „ „ in supply of provision without usurious prices.
57 „ „ by promotion of industrious and economic habits.
48 „ „ by benefits to tradesmen, mechanics and dealers.
98 „ „ by general advantage to the community.

The following number of institutions complain of difficulties:—

5 Difficulties arising from opposition.
17 „ „ from want of funds.
4 „ „ from improvident borrowers.
81 state that little or no difficulty has been experienced.
10 complain of loss of time to borrowers and loss of money to sureties.
1 speaks of intemperance and fraud.
9 mention the necessity of pawning to pay instalments.
91 state that there were little or no evils apparent.

The agricultural loan funds at Tyrrell's Pass and Moate are the most extensive, and a knowledge of their judicious management may lead others to follow their example. The first extends its operations over four hundred square miles; it has employed a Scotch agriculturist, and furnishes seeds to farmers. It also supports from its profits an infant school, in which 120 children are educated; a platting school for Irish Leghorn hats and bonnets has been commenced, and the manufacture of those articles from grass and rye-straw is of acknowledged beauty. A Ladies' Society is connected with the loan fund, which distributed at Christmas last 202*l*. worth of clothing, and 177 stones of wool were lent on three months' credit, and above 40*l*. given in premiums. The report of the agriculturists is most satisfactory. A meal-store was opened at the most trying season of the year, and employment afforded to 5229, who, with their families, constituted an aggregate of 19,795 souls, all deriving benefit from the employment afforded to one or more members of their families. The Moate Loan Fund has allocated 50*l*. per annum to an agricultural school. It is the only one in Leinster, and if properly supported by the landed proprietors, will doubtless prove a great benefit to the farming population. The sum of 80*l*. has been given as premiums to the farmers in those parishes from which the loan fund derives its profits. Forty pounds were also given to the Ladies' Charitable Association, which keeps forty poor women and girls in constant employment. On the branch of the system which embraces Monts de Piété, Mr. Porter referred to his paper read at Glasgow. He however stated that they are increasing in number, and are doing much to mitigate the evils of pawnbroking. At Limerick, Tandragee, Portadown, Belfast, Cork, Newcastle, and Dungannon, Monts de Piété are in active operation, and Coleraine and several other towns are in correspondence on the subject, with the view of opening such institutions. Mr. Porter then presented the following tables, explaining that the total number of loan funds was 215, of which three were closed, 73 had not yet made returns, and 66 kept no account of the subjects recorded in the second table.

Table of the Loan Funds in Ireland, from which returns have been received, showing the amount of Loans in the four Provinces.

Provinces.	Capital in circulation.	Total amount circulated.	Total number of loans in 1840.	Sums in borrowers' hands, 31st Dec. 1840.	Gross profits.	Expense of management.	Net profits.	Profits spent in charity.
	£	£		£	£	£	£	£
Ulster	88,515	523,415	138,560	124,631	18,577	6,089	6,367	2,821
Leinster.........	56,888	382,276	110,091	96,523	15,602	4,840	6,616	4,288
Munster.........	44,007	183,519	191,510	46,989	7,241	2,998	2,385	292
Connaught ...	5,929	76,364	240,010	19,178	2,584	1,124	478	147
Total......	195,339	1,165,574	464,171	287,321	44,004	15,051	15,846	7,548

Purposes for which Loans are granted by seventy-three Loan Funds, being about one-third of the number in existence.

Provinces.	Loans for horses, cows, and pigs.		Loans for seeds, manure, and implements.		Loans for meal, potatoes, &c.		Loans for wool, flax, and yarn.	
	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.
		£		£		£		£
Ulster	21,166	92,114	5,234	19,878	13,012	42,386	7,461	24,187
Leinster.........	11,620	47,113	2,744	10,013	5,921	16,802	830	2,683
Munster.........	4,255	10,973	589	1,236	4,118	8,336	797	1,927
Connaught ...	725	2,675	680	1,447	312	986	577	1,720
Total	37,766	152,875	9,247	32,574	23,363	77,510	9,665	30,517

Provinces.	Loans for looms.		Loans for iron, coal, timber, &c.		Loans for rent.		Loans for debts.		Loans for dealing.	
	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.	No.	Amt.
		£		£		£		£		£
Ulster......	417	1,422	4,466	17,358	4,308	18,498	1,633	5,210	6,469	28,212
Leinster ...	0	0	2,703	11,019	2,545	12,360	388	1,456	3,043	13,525
Munster...	43	45	3,874	8,955	922	2,395	290	920	4,337	11,060
Connaught	0	0	384	902	116	495	154	462	446	1,141
Total....	460	1,467	11,427	38,134	6,991	33,748	2,465	8,048	14,295	53,938

On the Income of Scientific and Literary Societies, and the Amount paid for Rates and Taxes in the year 1840. *By Mr.* A. RYLAND.

Number of societies.	Number of which amount of income is stated.	Amount of income.	Number of which amount of rates and taxes is stated.	Amount of rates and taxes.
112	91	£36,793 14 0	76	£1787 15 8

Institutions of which the amount both of Income and Expenditure is stated.

Number.	Income.	Taxes.	Per-centage.
82	£36,787 5 0½	£1,787 15 8	4½

Papers containing portions of a return of the Stipends of the Clergy of the Established Church in Scotland, were presented to the Section. From them it appeared that the average stipend of a clergyman in Berwick is 268*l.* per annum, in Roxburghshire 288*l.*, and in Haddington 360*l.*

Prof. Quetelet addressed the Section on the importance of keeping exact registers, in different districts, of the facts described in the following table:—

1. *Meteorology.*

Pressure of air.
Temperature.
Humidity.
Electricity.
Force and direction of winds.
Quantity of rain and snow, &c.
State of the sky.
Meteors, falling stars, &c.

2. *Physics.*

Magnetism of the earth.
Temperature at different depths.
Ditto at sources and mouths of rivers.
Temperatures of vegetables and animals.
Phænomena of tides.

3. *Chemistry.*

Analysis of air.
——— of rain water.

4. *Botany.*

Budding of plants.
Flowering.
Fructification.
Shedding of leaves.

5. *Agriculture.*

Epochs of rural labour.
——— of vegetable maturity.
——— of hay-making.
——— of vintages.

6. *Zoology.*

Arrival & departure of birds, insects, &c.
——— of fishes.
Entomological phænomena.
Reproduction of animals.
Mortality.

7. *Man.*

Births, and all their circumstances.
Deaths, and all their circumstances.
Diseases, and their duration.
Crimes.
Consumption of food.
Letters.
Traffic and travelling on roads.
——— on canals.
——— in harbours.

He stated, that from observation it appeared that there was a periodicity in the facts both of the physical and moral world. To tabulate these facts, to ascertain the times and circumstances of their maxima and minima, and to show where they coincided with each other, would be highly beneficial to science, and would render statistics the great bond by which all other branches of knowledge would be held together, and all applied to the service of man. He then went over the several heads of inquiry, briefly commenting on each.

Report on the state of Education in the Polytechnic School at Paris, prepared at the request of JAMES HEYWOOD, *F.R.S., by an English resident in Paris.*

The Polytechnic School of Paris is the principal educational institution in which pupils are prepared for the public service, in the departments of the artillery, engineering, and the construction of roads and bridges in France.

A severe preliminary examination is required from all the candidates who are desirous of admission into the Polytechnic School.

Two years' study are required from each of the pupils in the school, and the course of study consists, practically, of a continual series of examinations, which are often limited to particular branches of mathematical science, and are followed by more general examinations at the end of each academical year.

Public competition forms a part of the regulations for the entrance examination in the Polytechnic School, and no one can be admitted to this competition without having previously proved, that he is either French by birth, or French by naturalization, and that he is between sixteen and twenty years of age; soldiers only are permitted to enjoy a special exemption from this last rule, and they may be admitted to the competition, provided they have not attained their twenty-fifth year.

The subjects of the entrance examination include arithmetic, algebra, plane and descriptive geometry, plane and spherical trigonometry, logarithms, conic sections, and statics; exercises are also given in drawing from a model of the human figure, and in architectural coloured drawing; and the candidates are further expected to translate a passage from a Latin author, to write a French essay on a given subject, to work a trigonometrical question, and to compose a mathematical paper on some given problem, or on some other mathematical subject. Candidates are informed that all the foregoing subjects of the examination are equally obligatory upon them.

At the end of each academical year, the pupils of the school are subjected to severe examinations in analytical geometry, mechanics, physics, chemistry, descriptive geometry, the description and effect of machines, architecture, and several of the higher branches of algebra and mathematics.

Drawing and French composition are included among the subjects of study, and in the second year, the German language receives a portion of the attention of the students. A professorship of English was established in the school in 1830, at the same time with the German professorship, and both these important languages were taught in the school until the autumn of 1840.

The annual payment, or "pension," for education in the Polytechnic School is only 1000 francs, or 40*l*.; and there are also twenty-four bursarships, of 1000 francs each per annum, of which twelve are placed at the disposal of the minister of war, eight belong to the minister of the interior, and four to the minister of the marine, for the students. No pupil is, however, allowed to receive either a bursarship, or a half-bursarship, unless his name has been included in the first two-thirds of the admission list, and unless he has previously addressed a request for this emolument at the time of inscribing his name.

A strict system of military discipline is maintained in the school; duelling is forbidden, under pain of expulsion to both parties, if a challenge is accepted; games of chance are illegal, as well as smoking; and no books, printed papers, or drawings are allowed to be introduced, without special leave. Unconditional obedience to every command of the superior officers of the school, is a fundamental rule of the institution; the pupils are ordered on all occasions to salute their officers; they are required always to appear in their uniform, both in and out of school, and they are not allowed to hold or form any society, or secret deliberation, or to print anything in any periodical publication; and they must not even be present at any ceremony of any body or association, without the special permission of the commandant of the school.

Any pupil who remains absent from the school for three days, without communicating the cause to the commandant, ceases thereby to belong to the school. Two days only are allowed in each week on which the pupils may go out into the town; on Sunday, from the termination of the military parade, at a quarter past nine in the morning, until ten at night; and on Wednesday, from half-past two in the afternoon, until half-past eight P.M. in summer, and nine in winter. On these two days, the parents and guardians of the pupils, and persons furnished with permissions from them, are allowed to see the pupils in the parlour of the school, from three P.M. to a quarter before five P.M.

The pupils draw by lot for the seats which they occupy in the lecture-rooms, on first entering the school, and they always retain the same seats.

Exact notes are kept of their behaviour as well as of their proficiency, and marks of credit are granted to them accordingly.

A large staff of officers, examiners, and professors is maintained in the school, among whom are the well known names of Bourdon and Gay-Lussac: a certain number of extra masters are also privileged to give lessons in fencing, dancing, and music, and the school society is supplied with a physician, a surgeon, assistant surgeons, and numerous subordinate officers.

All the officers, including the commandant of the school, receive the full pay belonging to their rank, as well as one-third in addition to their pay, and the whole of the salaries are paid to the officers and others out of the funds of the school, which are included in the budget of the minister of war.

No ecclesiastical control is exercised over the students in the school, and no distinctions are made on account of religious opinions; persons of any denomination are admitted into the school, and in fact, the pupils are left entirely to themselves with respect to religion. The pupils are divided into four companies, to each of which are attached several sub-officers, out of their own body. They hold their rank only for one year, subject to re-appointment, and their promotion is considered as a mark of honourable distinction.

All orders of the superior officers are conveyed to the pupils of each company through these sub-officers, who are further responsible for the good conduct of their comrades, and are liable to be punished for them; the sub-officers of the school also wear the same gold chevrons on their uniform, which distinguish the sub-officers of the same grade in the army.

Those pupils who do not pass the examinations with credit at the end of the first year, cannot go up into the second year; and a similar failure at the end of another year, or even neglect during the daily examinations of the lectures, would cause them to be immediately dismissed from the school.

The place which they occupy at the end of the second year in the examinations, determines their order of admission into the public service; and as only very few are annually rejected, it may be said, that in general, the success of a candidate in the final examinations is always followed by a commission in the artillery, the engineers, the bridges and highways, the navy, or in some other department of the public service.

On the 1st of April 1840, there were 271 pupils in the Polytechnic School, of whom 139 were in the first year, and 132 in the second year: of the first-year men, four only had been recommended to pass a second year in the junior division of the school as they were not yet sufficiently advanced to enter on the second year's course of study; and in the second year, eight had been authorized to remain an additional year in the division, for various reasons.

Of the total number of 271 pupils, 56 were from the department of the Seine, in which Paris is situated, 208 from other French departments, 2 from French colonies, 2 of British parents, 1 from Switzerland, 1 from Saxony, 1 from Trebizond.

Besides these regular pupils, authorizations had been granted by the minister of war to twenty-six young men, who were not pupils of the school, to attend the lectures, viz. sixteen in the division of the first year, and ten in the division of the second year. These voluntary students were of various nations:—8 French, 1 English, 1 American, 2 Swiss, 3 Italian, 2 Greek, 1 Spanish, 2 Russian, 1 Norwegian, 1 Hessian, 1 Wurtemberger, 2 Portuguese, and 1 Brazilian.

The body of professors is always recruited by young men of the greatest promise, selected either from the school itself, or from the most distinguished scientific institutions of the country; the general course of the studies is superintended by a council of instruction, and the whole system is subject to the constant supervision of a council of improvement: these two councils are formed from the principal officers of the school, and other men of science, and to their vigilance and able direction the Polytechnic School is largely indebted for its efficiency.

A council of discipline watches over the internal regulations of the school, and the whole establishment is under the special jurisdiction and authority of the minister of war.

Results of some Experiments on a System of small Allotments and Spade Husbandry. By Mrs. DAVIES GILBERT.

It was stated that by this practice the number of paupers in the workhouse had been reduced from 220, July 1840, to 130, July 1841; and that the people evinced such a desire to obtain work that they walked three miles up Beachy Head for it. Mrs. Gilbert entered into minute details of the system of husbandry pursued in the district, particularly dwelling on the benefit of forming tanks in chalk soils, and the importance of keeping milch cows under cover.

Account of the establishment of a Central Statistical Commission in Brussels by the Belgian Government. By M. QUETELET.

He adverted to the great importance of statistical science, and dwelt on the difficulties which impede the collection, comparison and verification of statistics. He stated that government documents, even when trustworthy, presented difficulties in practical use, from their being constructed on various bases, published in different forms, and calculated on systems which did not admit of immediate comparison. He offered, on the part of the new Commission, to send copies of their publications to the statistical societies of Great Britain, from whom he requested communications in return.

MECHANICS.

On the Plymouth Breakwater. By Wm. Stuart, *C. E., Superintendent of the Work.*

The importance of a breakwater at Plymouth attracted the attention of the Admiralty in 1806, and in February of that year Mr. Rennie and Mr. Whidbey, the Master Attendant of Woolwich Dockyard, were directed to survey the Sound. As the results of their survey, they submitted a plan for a stone breakwater, and gave their opinions upon several plans previously proposed. The stone breakwater was to be 1700 yards in length, at the top of which the middle was to be straight for 1000 yards, and each end, 350 yards in length, was to incline at an angle of about 20° to the straight part: it was to be ten yards in width at the level of ten feet above the low water of an ordinary spring tide, with a slope of three to one on the south or sea side, and one and a half to one on the north or land side; and to be constructed by blocks of limestone thrown promiscuously into the sea on the intended line, with a cut stone pier on the top. This plan was favourably received, and an Order in Council was issued in June 1811, for the execution of the work, and in August 1812 the first stone was deposited. Mr. Stuart then described in detail the progress of the work, and the various alterations found advisable. The south slope is regularly formed with squared blocks of limestone and dove-tailed granite, from the level of low water spring tides, with a slope of five to one, and the north side with rough blocks of limestone, with a slope of two to one. A lighthouse is now in course of construction at the western end, and a buttress for the protection of the lighthouse, and securing the front of the south slope. The force of the sea is so great, that stones of fifteen or even twenty tons have been taken from low water and carried over the top of the work. According to the original calculation of Messrs. Rennie and Whidbey, 2,000,000 tons would be required for the work, but owing to the various extensions, the quantity is much increased, and between the 12th of August 1812, and the 31st of July 1841, 3,377,068 tons had been deposited. The estimated cost of the original breakwater was 1,013,900*l.*; but owing to the alterations in the work, and an increase in the materials, the whole outlay to the present moment is 1,111,700*l.*, and the cost of the breakwater when completed, including the lighthouse, will not exceed 1,300,000. Various other breakwaters have been proposed to the Admiralty: one of cast iron in 1804; two of stone, and one of wood, by Mr. Bentham, in 1811. The wooden breakwater was to consist of 117 floats of wood, of a triangular or prismatic form; each float thirty feet in breadth and depth, forty feet in length, to be moored by iron chains, at a cost of 201,805*l.*; but the Admiralty resolved on a stone breakwater, and the thirty years' experience since elapsed have confirmed the author in his opinion of the wisdom of the choice. The stone breakwater is said to have occasioned an accumulation of mud and silt within the harbour, and a consequent diminution in depth of the water to the extent of five feet. In the original report of Messrs. Rennie and Whidbey, is contained the following statement:—"From conversing with pilots and various other intelligent men whom we met at Plymouth, we have reason to believe, that the depth of water in the Sound is on the decrease, by the settlement of mud and silt brought down by the rivers from the interior country, and also by the embankment of the mud lands within, thus diminishing the ancient receptacles of the water of the tide, which both in its flux and reflux occasions a powerful scour in its passage through the Sound." The fact is, that a recent inclosure of 275 acres of the backwater of the Catwater above the Lara Bridge had just taken place; it seems evident that mud and silt were then in the Sound. On a consideration of the whole question, Messrs. Rennie and Whidbey were of opinion that there was no danger of the Sound becoming more shallow, and that no further deposition of silt or mud would take place, except immediately within or without the breakwater. In consequence of a communication, made in July 1838, to the naval authorities at this port, to the effect that a deposit was then going on in the Sound, the Admiralty directed Mr. James Walker to report fully on the subject, and the best means for providing against the apprehended injury to the anchorage. After a long and laborious investigation, and a minute survey, during which no less than 2000 soundings were taken, Mr. Walker reported, that, taking the mean of the soundings that could be affected by the breakwater, the result was that there was but very little increase or decrease, and that, if there was any decrease of depth in the Sound (except close to the breakwater, and which could produce no practical evil), this was certain, that if it had taken place, it was but small,—certainly not enough to cause alarm, or to justify expensive measures for removing the cause. As to the destruction of the breakwater by the Pholas, though connected with the breakwater since its commencement, Mr. Stuart never saw a perforation in the limestone by the Pholas, except between the low water of spring and of neap tides; and these perforations only occur on the outer surface of the stone, and to a depth not exceeding three inches. He never discovered any such perforation in the interior of the work, although he had recently had occasion to remove stones, by the aid of the diving-bell, at the depth of five feet below low water, and which had been deposited there upwards of twenty-five years. Loose stones had been taken up from beaches, and from the bottom of the Sound, perforated by the Pholas, but they must have been perforated before they got there, for the Pholas had never, in such cases, been found alive.

On a Floating Breakwater. By Captain TAYLOR, *R.N.*

The breakwaters hitherto constructed have generally consisted of solid masonry, thus presenting an unyielding obstacle to the waves, permitting accumulations of mud and sand behind them, causing enormous outlay by the constant dilapidation from the force of the waves and compressed air, and not affording the security to shipping and life which is required, and may be afforded by other means. The floating breakwater consists of floating sections framed of timber strongly moored; these sections yield to the shocks of the sea, and admit the waves to pass through them, and by thus dividing the waves, reduce them to an open and harmless state. The depth of these sections vary according to the situations in which they are employed. The sea in the most tempestuous weather is said to be tranquil at the depth of sixteen or eighteen feet below the surface; a breakwater, therefore, immerged to that depth, and presenting six or eight feet above the surface, is sufficient to form a safe harbour on the most boisterous coast. The angle of inclination which the section presents to the wave is that pointed out by nature in the Mew-stone, viz. 35 degrees. Stone breakwaters check the ground tides, and cause accumulations of mud and deposits which otherwise would go seaward, and are peculiarly subject to the action of boring shells, constantly at work below the dove-tailed stone; and cavities being formed, large portions are occasionally blown up. The destruction of the wood by the Teredo is prevented in the floating breakwater by tarring the wood with a preservative mixture, and the worm can make no lodgment on a prism floating upon the surface; besides, it can be scrubbed and tarred as often as required. The distinction between waves and breakers is very important, the former being an undulation, the latter being accompanied with a translation of the mass, and capable therefore of exerting extraordinary forces on the masses opposed to them, when applied force to force. The breakwater is formed of hollow framework; it fills with an inert body of water, which requires a considerable force to be put in motion or driven through the breakwater, and each succeeding wave expends its force upon the preceding, therefore each wave becoming inert, acts as a resisting medium to the others, almost entirely independent of the caisson itself, with but slight strain to the moorings, and thus passes broken and tranquil to the inner or land side, which is rendered completely calm, instead of acting with immense violence upon solid masses. The construction of this breakwater is so adjusted that its beam is limited to 20 feet, for beyond this it would present too solid a resistance, and add to the strain on the moorings and framework. This was clearly demonstrated by practical experiments.

Capt. Taylor, R.N. explained, by reference to a model, his construction and application of a shield to protect the paddle-wheels of steam-boats from the shock or action of the sea when riding at anchor, or sailing or scudding under canvas when the steam power is not applied; also his method of disconnecting the paddles without stopping the engines. He also proposed to apply the steam power of vessels for the purpose of working the windlass.

On the Propulsion of Vessels by the Trapezium Paddle-wheel and Screw. By G. Rennie, *F.R.S.*

The author gave an account of the various experiments to which he had been led, on the propulsion of vessels by various forms of paddle-floats and by the screw. It was generally admitted that the paddle-wheel was the best means of propulsion with which engineers were at present acquainted, and various attempts had been made for its improvement. There are several objections to the square or rectangular floats, particularly the shock on entering the water, and the drag against the motion of the wheel on the float quitting the water; both of which give rise to considerable vibrations. He had been led, in considering the improvement of the paddle-wheel, to have recourse to nature, and the form of the foot of the duck had particularly attracted his attention. The web of the duck's foot is shaped so that each part has a relation to the space through which it has to move, that is, to the distance from the centre of motion of the animal's leg. Hence he was led to cut off the angles of the rectangular floats, and he found that the resistance to the wheel through the water was not diminished. Pursuing these observations and experiments, he was led to adopt a float of a trapezium or diamond shape, with its most pointed end downwards. These floats enter the water with their points downwards, and quit it with their points upwards; they arrive gradually at their full horizontal action, without shocks or vibrations, and after their full horizontal action, quit the water without lifting it, or producing any sensible commotion behind. After a great variety of experiments, he found that a paddle-wheel of one half the width and weight and with trapezium floats, was as effective in propelling a vessel as a wheel of double the width and weight with the ordinary rectangular floats. The Admiralty had permitted him to fit Her Majesty's steam-ship *African* with these wheels, and he had perfect confidence in the success of the experiment. Another means of propulsion was the screw, which had been applied with success by Mr. Smith in the *Archimedes*. In examining the wings of birds and the tails of swift fish, he had been particularly struck with the adaptation of shape to the speed of the animals. The contrast between the shape of the tail of the codfish, a slow-moving fish, and the tail of the mackerel, a rapid fish, was very remarkable,—the latter going off much more rapidly to a point than the former. From these observations he was led to try a screw with four wings, of a shape somewhat similar to these, but bent into a conical surface, the outline being a logarithmic spiral. He found also that certain portions of these might be cut off without diminishing the effect. With respect to ascertaining the friction of the screw on the water, great difficulty existed; but he would refer to his experiments, published some years ago in the Philosophical Transactions, in which he measured the friction of the water against a body revolving in it, by the time which a given weight took to descend; this body consisted of rings, and he found that the friction or resistance through the water did not increase in proportion to the number of rings. The results of the experiments made since with the African, opposite the measured mile in Long Reach in the river Thames, and also with an iron steam-boat in the river Shannon, have fully realized the expectations of the author.

On Truscott's Plan for Reefing Paddle-Wheels. By W. Chatfield.

Mr. Chatfield described, by reference to a model, an improved paddle-wheel, the principal feature of which was a new application of the principle of feathering and reefing. Each paddle or float is attached to an axis passing through its centre, with a crank at the extremity of the axis, and the feathering is effected by the motion of a roller attached to this crank, and moving in a groove eccentric to the wheels. The radii of the paddle-wheel are connected at their extremities by a chain instead of a rigid rim, and the reefing is effected by drawing the radii together, like the folding of a fan, by means of a peculiar arrangement of the clutch box at the centre of the wheel.

On a Plan of Disengaging and Reconnecting the Paddle-Wheels of Steam-Engines. By J. GRANTHAM.

There are four cases in which it may be desirable to disconnect the paddle-wheels from the steam-engine in steam vessels, viz. when the vessel is on a long voyage, and the fuel must be economized as much as possible by using the sails on every favourable opportunity; when the engines are damaged, and, the vessel being close to a lee shore, it is necessary to disengage the engines quickly, to allow the vessel to make sail; when some derangement has taken place, and the engines are allowed to continue to work imperfectly to the end of the voyage, rather than detain the vessel by causing the paddles to drag through the water while the engines are stopped; when, the vessel being at anchor, the action of the swell and tide on the paddle-floats, while stationary, causes a great additional strain on the cables, which would be obviated could the wheels play freely. The Admiralty had called attention to the subject, by inviting plans for effecting it. Several had been proposed for disconnecting the paddles, but Mr. Grantham is not aware of any plan having been proposed by which the wheels could be readily reconnected in a heavy sea. The crank pins are usually fixed in the cranks of the intermediate shaft, a little play being allowed in the eye of the crank of the paddle shaft, to prevent the crank pins from breaking when the centres of the three shafts vary from a straight line by the yielding of the vessel. For the purpose of disengaging and reconnecting, a brass box of a rectangular form is inserted in the eye of the crank of the paddle shaft, which can be moved several inches by means of a screw at the back of the crank. The eye of the crank is so made that two of its sides may be cut away, and through these openings the crank pin can pass when the box is drawn back, or the disengaging effected. The brass box has one of its sides, which restrain the crank pin when in gear, cut away one or two inches to assist in reconnecting the engine, which is effected by screwing the box out one or two inches, or just so far that the crank pin can pass the side which has been cut away, and come in contact with the higher side. This is the correct position for reconnecting, which is accomplished by a single turn of the screw.

On Captain Couch's Chock Channels.

Mr. Snow Harris explained and illustrated, by a model and drawings, the safety chock channel, for allowing the masts and rigging of vessels to be easily disengaged when the masts are carried away. Many cases have occurred in which, with the rigging and ordinary channels, the greatest danger has been incurred, in consequence of not being able to get clear of wreck. The ordinary channels may be blown up by the sea; whereas, if made solid, on Capt. Couch's plan, all danger from this source will be avoided, and the sailors would be at once able to clear the vessel of any wreck.

On a System of Trussing for the Roadways of Suspension Bridges. By J. M. RENDEL.

Mr. Rendel placed before the Section a model of the Montrose Suspension Bridge, the roadway of which had been recently restored, and a peculiar system of trussing adopted. Suspension bridges were peculiarly subject to undulatory motions, which proved extremely destructive to them. These undulatory motions arise from the action of the wind, and the circumstances are such that the wind may tend to raise the roadway at one end, and depress it at the other; and various means had been devised to prevent these motions. In 1838 a considerable portion of the roadway of the Montrose Bridge was destroyed, and Mr. Rendel being employed to restore it, it struck him that if great stiffness were given to the roadway by a system of longitudinal trussing, the desired object would be attained. He adopted, therefore, a system of vertical and longitudinal trussing, extending above and below the line of the roadway, so that the neutral axis of the truss is in the roadway. This had succeeded most completely. In an ordinary gale of wind, the original roadway would be subject to a wave of from three to five feet in height, but he was satisfied that the present roadway is not subject to a wave of as many inches. The weight of the roadway has not been increased by more than five or six per cent.

Remarks on the Connexion which exists between Improvements in Pitwork and the Duty of Steam-engines in Cornwall. By J. S. Enys.

After adverting to the admission of the truth of progressive increase of duty, it was shown that considerable changes have been made in the course of seventy years, in the methods by which water is lifted out of the mines in Cornwall; and that in comparing the duty of earlier periods, an allowance of the difference of the Imperial and Winchester bushel of coal ought to be made. The distinction between horse-power and duty, pointed out by Mr Parkes, was alluded to: one excludes, the other includes, the friction of the pitwork; and the remarks attached to each in Lean's report, show the necessity of adverting to the different conditions of the pitwork, in an attempt to estimate with accuracy the relative merit of different engines separate from the pitwork. In an endeavour, some time ago, to trace the causes of the great variation of the duty, a small amount of expansion was observed in engines remarkable for a low duty, and the reasons assigned were, either weak pitwork—flat rods—heavy load per square inch on the piston, and old boilers—and often the joint action of the above causes. The strength of the pitwork, or of the boilers, in different cases, seems to become the limit of expansion in the engines. In reference to deficiency of water from pumps, in proportion to the calculated quantities, on which duty is founded, two causes have operated in inducing a strong belief that it is less than at any former period:—1. Greater attention to the pitwork by the managers of the mines, under whose care it is placed, to the exclusion of the engineers of the steam-engine by which it is worked. 2. The general employment of the plunger-pump,—the latter instantly shows the slightest defect of the packing, and allows of an easy remedy; while the bucket-pump, on the contrary, does not show the defects in the packing; and the operation of tightening it is attended with great difficulty,—so much so, as often to cause the repacking to be delayed to the last moment that the pump will lift water. The first cause, though it has a tendency to decrease duty in proportion to improved water delivery, has in a still greater degree the tendency to reduce the friction of the pitwork on a given load: yet it is not easy to assign the exact values: on the whole, a reduction of total resistances probably occurs in shafts of equal depth; but, on the other hand, the great increased depth of many shafts obviously produces a greater proportional friction on a given load. Under these circumstances, it becomes the fairer method to select the duty of engines working the deepest shafts, for a comparison with the duty of the earlier periods, when engines were worked so differently as regards the steam. Mr. J. W. Henwood (Huel Towan) estimates the deficiency of water delivery at 7 or 8 per cent.; Mr. T. Wicksteed (Holmbush) 10 per cent. water from three lifts measured and weighed; Mr. Enys (Eldon's engine, United Mines) 4 per cent., four strokes of the engine with one plunger-lift having been measured. The absence of attention in earlier times can only be assumed from the known habits of the miner, and the absurd stories prevalent of particular instances of neglect. Another great, but almost inappreciable change, has occurred in the increase of weight in the rods for a given load, due to deeper shafts and more expansion; but the circumstance of the greater weight of rods admitted of the reciprocal action of a still greater amount of expansion in Watt's engines: in heavy pitwork, the accumulated force stored up at the commencement is restored at the end of the stroke. The only decrease of duty is occasioned by a greater amount of friction in the gudgeons of the balance beams, arising from the weights required to balance the rods; but, on the other hand, a direct gain is obviously due to the smaller quantity of water required to be expended as steam, to produce, by means of greater expansion, the same mean power. The present form of rod, with lifts alternately on each side, where the shaft admits of this method, was probably due to Watt or Murdoch. Smeaton, at the Chacewater Atmospheric Engine, in 1775, seems to have effected the introduction of one rod for a portion of the shaft, and dispensed with the older practice of bringing up to the arc of the beam a separate rod for each lift. The plunger-pump seems to have effected another change of some importance, in the velocity with which the larger portion of water is raised. The engines are usually made to go, out-of-doors, at rather more than half the velocity of the in-door stroke, the piston moving in-doors from 240 to 260 feet, and out-of-doors from

120 to 130 feet per minute; the velocity of the plunger is usually four-fifths of this amount, or 100 to 120 feet per minute. Still a portion of the water, from one-third to one-sixth, is raised at three-fourths of the higher velocity; recently larger valves have been placed below the plunger than above, with a view of equalizing the resistance of the water on passing the valves. In commencing motion, after the state of rest to which pumping engines are brought, it is possible a greater power may be employed than is required to continue it; still the term variable load, formerly adopted by the writer of this paper, may be too strong. In an attempt to value friction by the area of the rubbing surfaces of the packing of the plungers, it appeared the unanimous opinion of many of the best pitmen, that water could be kept from escaping with less friction by means of twelve-inch than with nine-inch packing, in a twelve-inch plunger-lift,—a circumstance that requires attention, not only in this, but probably under numerous other conditions of friction calculations. In regard to the effect of expansion on the pitwork in producing a variable strain during the load, it was observed, that with twelve times expansion on an engine recently erected, of Watt's construction, including clearance steam, the variation was found by an indicator to be as 8 to 1 at the end of the stroke; but that in a new engine with combined cylinder, by Sims, in which the steam is expanded twelve times, viz. three times in a small cylinder, and subsequently four times in a larger cylinder during the out-door stroke, this power being converted into a constant quantity in-doors by means of a balance, the variation of pressure would be about as 2 to 1 only; and that in Hornblower's or Woolf's, if worked with high steam, under the condition of twelve times expansion, including clearance steam, the variation might be roughly taken as 3 to 1; —that the commercial part of the question of more or less expense in engines or pitwork, would determine the relative advantages, on the whole, of each engine for lifting water from deep mines. It seems that expansion has not been carried out to so great an extent when the load is near the end of the beam, and when the enormous balance weights, usual in Cornish pitwork, are not required to be applied, though it is obvious that this condition causes less pitwork friction.

On an improved Sight for Rifles and other Fire-arms. By CHARLES THORNTON COATHUPE.

As a substitute for the ordinary steel-leaved rifle sight, whose heights are regulated for certain definite ranges (between which an imaginary allowance for the correct elevation is all that can be effected), Mr. Coathupe recommends another upon a different principle, equally simple, and by which any elevation may be readily obtained with accuracy, commencing with the lowest, or point-blank range, and ascending by the least possible increments to the extreme range for all useful purposes.

It should be constructed by first forging a piece of iron, which, when filed up flat, and square at the edges, shall furnish a wedge, or inclined plane, from six to eight inches in length, and from three-eighths to half an inch in width, having its thicker extremity about three-eighths of an inch, and its thinner end about one-sixteenth of an inch in thickness.

Upon this inclined plane a piece of steel, of similar length and width to that of the inclined plane, but of uniform thickness throughout, and having its edges filed so as to exhibit a dove-tail section, must be fixed, the wider surface being uppermost. Upon this dove-tail plate a steel sight, with a small notch filed in the centre of its upper edge, must be fitted so as to traverse steadily from end to end. The dove-tail plate may be attached to the inclined plane by means of gunsmiths' solder; and when thus fixed, a narrow groove must be filed longitudinally through its substance, commencing in a median line upon its upper surface, the bottom of the groove being parallel to the base of the inclined plane. The whole must then be affixed to the rifle barrel, in a line corresponding with the axis of the bore, by means of three steel screws, whose heads must be countersunk.

It is evident, that if the upper edge of this traversing sight, when at the commencement of the inclined plane, be so adjusted to the perpendicular heights of the inclined plane, and of the sight near the muzzle, that a line passing through a central point in each shall be parallel to the axis of the bore, this will be the position for the point-blank range of the rifle; also, that if the traversing sight be pushed further along the inclined plane, the angle of elevation, and consequently the range, will be proportionally and gradually increased, until it has traversed to the extent of its limit: and as, during its passage, it will be gradually approximating to the upper sight, there will be an increasing ratio of range as the distance between the two points of sight diminishes.

The plate upon which the lower sight traverses should be graduated throughout its length for every ten yards of distance within the range of the barrel (the charge and quality of the powder being uniform). By means of the thumb, the sight may be instantly adjusted to accord with the estimated distance of the object from the observer.

On the Granite Quarries of Dartmoor, and their Railways and Machinery. By W. Johnson.

The surface granite of Dartmoor, existing in detached blocks, has been long employed in the neighbourhood for ordinary building purposes, but the quarried granite was first brought into the market by the Haytor Granite Company about the year 1820. The construction of a stone tramway allowed of the granite being shipped at Teignmouth; it now competes with the best Aberdeenshire stone, since the lightness of its tint, the fineness of its texture, and the very large blocks in which it can be obtained, render it for some purposes unrivalled, and it has been extensively employed in many public buildings, both in the metropolis and other places. The completion in 1825 of the Plymouth and Dartmoor Railway, of the length of 25 miles and uniform rise of 1 in 94, affords ready transport for the granite of the western face of the moor from Fogginton and other parts adjacent, and the facilities with which these quarries are worked are very great. Strong timber stages with travelling frames, and upon the frames powerful traversing crabs, avoiding thereby the labour and delay of lifting by the ordinary means of derricks and cranes, are now in the course of construction. The travelling frames, with the crabs upon them, can be transferred from one line of scaffold to another, so that power may be accumulated to any extent upon one stage, so as to operate on blocks of extraordinary size. The magnitude of the blocks in which the granite can be procured from this quarry, renders it peculiarly fitted for the largest works of the engineer. The beds already accessible lie at great depths below the surface, and yield stone of the greatest compactness, strength, and uniformity of colour, and the horizontal disposition of the rock allows of the removal of stone of fair forms and in blocks of the largest size.

On Arnott's Stove, and the Construction of Descending Flues, and their Application to the purposes of Ventilation. By J. N. Hearder.

The general advantages of Arnott's stoves in economizing fuel, avoiding smoke, and regulating the temperature, are well known; but these stoves are attended with some disadvantages, of which the danger of explosion and imperfect ventilation are the most serious. The liability to explosion Mr. Hearder considers to arise from the construction of the stove, in having the upper door air-tight, the only aperture for air being the valve aperture of the ash-pit. The air so admitted is immediately decomposed, and nearly the whole of its oxygen is abstracted, so that by the time it has passed up through the fuel, and reached the upper chamber of the stove, it has not oxygen enough left to support combustion. The heat evolved by the lower stratum of fuel, acting upon the upper stratum of fresh or unignited fuel, liberates from it the inflammable gas which it contains, and which also accumulates in the top of the stove. A mixture is then formed analogous to the fire-damp of coal mines, ready for explosion whenever the requisite oxygen or degree of temperature shall be present. Under these circumstances, should the door be opened, a burst of flame outwards may be the result; or should a puff of wind down the chimney carry the mixture down through the ignited fuel, an explosion may ensue. Other causes, such as the sudden shutting or opening of the door of an apartment, may occasion the downward draught and consequent explosion. Now carburetted hydrogen will not explode when the proportion of the air to the hydrogen exceeds a certain limit, so that if air be supplied to the top of the stove, so as greatly to preponderate over the hydrogen, the latter will burn off in flame at the moment of its formation, or be carried up the flue. Mr. Hearder, therefore, proposes as a remedy, perforations through the lower edge of the upper door, so that air may be admitted on a level with the top edge of the fire-brick, through which a constant in-draught of atmospheric air will be ensured, sufficient to obviate the evil. The heat evolved by the perfect combustion of this inflammable gas, under these circumstances, will, he says, more than compensate for the admission of cold air into the upper part of the stove. The perforations just mentioned will also obviate, in a great measure, the want of ventilation. The author described a small rarefying apparatus, to be inserted in the vertical shaft connected with a descending flue, in which apparatus a small culm fire is to be constantly kept. The expense of this is not more than one penny per day; and Mr. Hearder has found by experience that the draught produced by this means is so powerful as to ensure the success of an underground flue several hundreds of feet in length.

On the Water Power at Wheal Friendship Mine. By JOHN TAYLOR, *F.R.S.*

On the present state of the Thames Tunnel. By Sir ISAMBARD BRUNEL.

Mr. Whitworth gave an account of 'A New Construction of Die Stock for Cutting Screws.'

Mr. D. Laing explained 'Smith's Wire Ropes.'

Mr. Brockedon explained his 'Application of Caoutchouc as a Stopper for Bottles containing Liquids.'

INDEX I.

TO

REPORTS ON THE STATE OF SCIENCE.

OBJECTS and rules of the Association, v.
Officers and council, vii.
Places of meeting and officers from commencement, viii.
Officers of sectional committees at the Plymouth Meeting, xi.
Corresponding members, xi.
Treasurer's account, xii.
British Association property, xiii.
Reports and desiderata, &c., xiv.
Arrangement of the General Evening Meetings, xv.
Researches published by the British Association, xvi.
Recommendations for reports and special researches in science, xix.
Reports undertaken to be drawn up at the request of the Association, xix.
Recommendations of researches in science involving money grants, xx.
Synopsis of money grants, xxiv.
Extracts from resolutions of the General Committee, xxv.
Address by the Rev. Professor Whewell, President, xxvii.

Acid, carbonic, formation of, in the animal body, 27.
——, effect of, when injected into the veins, 28.
——, ——, when thrown into the carotid artery, 28.
Agassiz (M.), provision of meteorological instruments for the use of, 41.
Air, velocity of cooling in, 5.
Airy (G. B.) on the publication of the hourly observations made at Plymouth, 328.
Anemometer, Osler's, erection of, at Inverness, 329.
——, Whewell's, on the working of, at Plymouth, 36.
Animals, engraving of skeleton maps for recording the distribution of, 327.
Anoplura Britanniæ, 331.
Artery, effects of carbonic acid when thrown into the carotid, 28.

Baily (F.) on revising the nomenclature of the stars, 44.
Baily (F.) on the reduction of the stars in the *Histoire Céleste*, 330.
—— on the extension of stars in the Royal Astronomical Society's catalogue, 330.
Ball (R.) on marine zoology, 331.
Balloons, experiments with, 55.
——, directions for making observations on the atmosphere in, 59.
Barometer, on the, 58.
Batrachia, 181.
Birt (W. R.) on meteorological observations made in America, 43.
Brewster (Sir D.) on experiments with balloons, 55.
—— on the hourly observations at Inverness and Unst, 329.
—— on the erection of Osler's anemometer at Inverness, 329.
—— on the action of gaseous and other media on the solar spectrum, 330.
Bristol tides, discussions of, 30.
Bryce (J., Jun.) on earthquakes in Ireland, 49.
—— on the subject of researches concerning the mud of rivers, 330.
Buckland (Dr.) on the fossil fishes of the old red sandstone of Great Britain, 331.
—— on drawings of the sections of strata exposed in railway excavations, 331.
Bunt (Mr.) on discussions of Bristol tides, 30.

Cape of Good Hope, magnetic disturbance at, on Sept. 24 and 25, 1841, 351.
Caprimulgidæ, progress of report on, 331.
Cetiosaurus, 94.
—— brevis, 94.
—— medius, 100.
—— brachyurus, 100.
—— longus, 101.
Chelone, 168.
—— planiceps, 168.
—— obovata, 170.
——, Wealden, 172.
—— pulchriceps, 172.
——, Eocene tertiary, 177.
—— longiceps, 177.
—— planimentum, 178.
—— breviceps, 178.

Chelone convexa, 178.
—— subcristata, 179.
—— latiscutata, 179.
Chelonia, 160.
Chelonidæ, 168.
Cladyodon, 155.
Cœlum Australe Stelliferum, reduction of Lacaille's stars in the, 327.
Compteur, Morin's, 309.
Conduction, power of, 5.
——, Fourier's hypothesis of, 6.
Cooling, Newton's law of, 3.
Crocodilia, 65.
Crocodilus Spenceri, 65.

Dalyell (Sir J. G.) on radiata, 331.
Denny (Mr.) on anoplura Britanniæ, 331.
Dinosaurians, 102.

Earthquakes, on obtaining instruments and registers to record shocks of, in Scotland and Ireland, 46.
Ely (The Very Rev. the Dean of) on terrestrial magnetism and meteorology, 38.
Emydian, large, from the Kimmeridge clay, 168.
——, footsteps of, in new red sandstone, 168.
Emys, 160.
—— testudiniformis, 161.
—— de Sheppey, 161.
Enys (J.) on the construction of a constant indicator for steam-engines, 307.

Fossil reptiles, British, 60.
—— fishes of the old red sandstone of Great Britain, 331.
Femur, chelonian, from lias at Linksfield, 168.

Gases, velocity of cooling in, 5.
Goniopholis crassidens, 69.
Gould (Mr.), progress of report on caprimulgidæ, 331.
Graham (Robert) on the engraving of skeleton maps for recording the distribution of plants and animals, 327.
Greenock (Lord) on obtaining instruments and registers to record shocks of earthquakes in Scotland and Ireland, 46.

Harris (W. S.) on the working of Whewell's anemometer at Plymouth, 36.
—— on the publication of the hourly observations made at Plymouth under the superintendence of, 328.
Heat, present state of our theoretical and experimental knowledge of the laws of conduction of, 1.
——, Poisson's theory of, 9, 11.
——, Fourier's hypothesis of, 9.
——, Libri's hypothesis of, 10.
——, Biot on, 15.
——, conductive power relative to, 18.
Herschel (Sir J. F. W., Bart.) on terrestrial magnetism and meteorology, 38.
—— on the reduction of meteorological observations, 42.
Herschel (Sir J. F. W., Bart.) on revising the nomenclature of the stars, 44.
—— on experiments with balloons, 55.
—— on the reduction of Lacaille's stars in the Cœlum Australe Stelliferum, 327.
Histoire Céleste, reduction of stars in the, 330.
Hodgkin (Dr.) on inquiries into the races of man, 52.
Hodgkinson (Eaton) on the construction of a constant indicator for steam-engines, 307.
Human race, varieties of the, 332.
——, queries respecting the, 332.
——, physical characters, 332.
——, language, 334.
——, individual and family life, 335.
——, buildings and monuments, 337.
——, works of art, 337.
——, domestic animals, 337.
——, governments and laws, 337.
——, geography and statistics, 338.
——, social relations, 338.
——, religion, superstitions, &c., 339.
Hygrometer, on the, 58.
Hylæosaurus, 111.
——, vertebræ of, 112.
——, sacrum of, 113.
——, caudal vertebræ of, 114.
——, dermal scutes of, 115.
——, dermal spines of, 115.
——, scapular arch of, 117.
——, teeth of, 118.
——, jaw of, 119.
Hythe, gigantic fossil saurian from the lower greensand at, 157.

Iguanodon, 120.
——, teeth of the, 120.
——, head of, 124.
——, tympanic bone of, 124.
——, vertebral column of, 125.
——, sacral vertebræ of, 129.
——, caudal vertebræ of, 131.
——, ribs of, 133.
——, scapular arch of, 133.
——, coracoid of, 134.
——, clavicle of, 134.
——, humerus of, 135.
——, ilium of, 135.
——, pubis of, 135.
——, ischium of, 136.
——, femur of, 136.
——, size of, 142.
Iguanodon Mantelli, 120.
Indicator, constant, construction of a, for steam-engines, 307.
——, Watt's, 308.
——, Prof. Moseley's, 310.
——, theory of the, 314.
Inverness, erection of Osler's anemometer at, 329.
——, hourly observations at, 329.
Ireland, on obtaining instruments and registers to record shocks of earthquakes in, 16.

Jardine (Sir W., Bart.) on anoplura Britanniæ, 331.

Kelland (Rev. P.) on the present state of our theoretical and experimental knowledge of the laws of conduction of heat, 1.
Kimmeridge clay, large emydian from the, 168.

Labyrinthodon leptognathus, 183.
—— pachygnathus, 186.
—— scutulatus, 188.
Lacaille's stars in the Cœlum Australe Stelliferum, reduction of, 327.
Lacertilia, 144.
Lardner (Dr. D.) on the determination of the mean value of railway constants, 205.
Leiodon, 144.
Leith tide observations, discussion of, 33.
Lizard, pleurodont eocene, 145.
——, oolite, 145.
Lloyd (Prof.) on terrestrial magnetism and meteorology, 38.
Lubbock (Sir J. W., Bart.) on experiments with balloons, 55.

Magnetic disturbance at Toronto on the 25th and 26th Sept. 1841, 340.
——, remarks relative to the, 345.
——, at Trevandrum, on Sept. 25, 1841, 347.
——, at St. Helena, on Sept. 24 and 25, 1841, 349.
——, at the Cape of Good Hope, on the 24th and 25th Sept. 1841, 351.
Magnetism, terrestrial, 38.
Man, inquiries into the races of, 52.
Maps, skeleton, engraving of, for recording the distribution of plants and animals, 327.
Megalosaurus, 103.
——, vertebræ of, 104.
——, sacrum of, 105.
Meteorological instruments, provision of, for the use of M. Agassiz and Mr. M'Cord, 41.
Meteorological observations, reduction of, 42.
Meteorology, 38.
M'Cord (Mr.) provision of meteorological instruments for the use of, 41.
Miller (Prof. W. H.) on experiments with balloons, 55.
Milne (David) on obtaining instruments and registers to record shocks of earthquakes in Scotland and Ireland, 46.
—— letter to, from J. Bryce, Esq., on earthquakes in Ireland, 49.
Morin's compteur, 309.
Mosasaurus, 144.
Moseley (Prof.) on the construction of a constant indicator for steam-engines, 307.
Mud of rivers, researches concerning the, 330.

Newton's law of cooling, 3.

Ophidia, 180.
Ornithology, progress of report on, 331.
Owen (R.) on British fossil reptiles, 60.

Palæosaurus, 154.
Patterson (Rob.) on marine zoology, 331.
Plants, engraving of skeleton maps for recording the distribution of, 327.
Platemys Bowerbankii, 163.
—— Bullockii, 164.
—— Mantelli, 167.
Pliosaur, teeth of the, 61.
——, vertebral column of, 62.
——, bones of the extremities of, 64.
Pliosaurus, 60.
Plymouth, on the working of Whewell's anemometer at, 36.
——, hourly observations made at, 328.
Poikilopleuron Bucklandi, 84.
Poisons, 26.
Polyptychodon, 156.
Pterosauria, 156.

Radiation, law of, 2.
Railway constants, determination of the mean value of, 205, 247.
Raphiosaurus, 145.
Reports, provisional, 327.
Reptiles, British fossil, 60.
Researches, progress in special, 327.
Rhynchosaurus, 145.
——, vertebræ of the, 146.
——, skull of, 147.
——, coracoid of, 151.
——, humerus of, 151.
——, radius and ulna of, 152.
——, ilium of, 152.
——, femora of, 152.
Robinson (T. R.) on experiments with balloons, 55.
Ross (D.) on the discussion of Leith tide observations, 33.
Roupell (Dr. G. L.) on poisons, 26.
Russell (J. S.) on the forms of vessels, 325.
—— on waves, 325.
Rysosteus, 159.

Sabine (Lieut.-Col.) on terrestrial magnetism and meteorology, 38.
—— on experiments with balloons, 55.
—— on the translation of foreign scientific memoirs, 328.
Saurian, gigantic fossil, from the lower greensand at Hythe, 157.
——, femur of the, 157.
——, tibia and fibula of, 157.
——, metatarsals of, 158.
——, ilia, ischia, pubis, and coracoid bone of, 158.
Scientific memoirs, translation of foreign, 328.
Scotland, on obtaining instruments and registers to record shocks of earthquakes in, 46.
Seeds, preservation of vegetative powers in, 50.
Seismometer, common pendulum, 46.
——, inverted pendulum, 47.
Selby (Mr.) on ornithology, 331.
Spectrum, solar, inquiry into the action of gaseous and other media on the, 330.

Stars, nomenclature of the, 44.
——, reduction of, in the *Histoire Céleste*, 330.
——, extension of, in the Royal Astronomical Society's catalogue, 330.
Steam-engines, formulæ for determining the work of, by means of the indicator, 323.
——, construction of a constant indicator for, 307.
Steneosaurus, 82.
St. Helena, magnetic disturbance at, on Sept. 24th and 25th, 1841, 349.
Strata, progress of drawings of the sections of, exposed in railway excavations, 331.
Streptospondylus, 88.
—— major, 91.
Suchosaurus cultridens, 67.

Teleosaurus, 72.
——, vertebral column of the, 76.
——, pectoral extremities of, 78.
——, dermal armour of, 79.
Teleosaurus cadomensis, 81.
—— asthenodeirus, 81.
Testudinidæ, 160.
Thecodonts, 153.
Thermometer, on the, 59.
Tide observations, discussion of Leith, 33.
Tides, discussions of Bristol, 30.
Toronto, magnetic disturbance at, on the 25th and 26th Sept. 1841, 340.
Tortoises, new red sandstone, 160.
Tortoises, oolite, 160.
Tretosternon punctatum, 165.
Trevandrum, magnetic disturbance at, on Sept. 25th, 1841, 347.
Trionyx, 168.

Unst, hourly observations at, 329.

Vegetative powers in seeds, preservation of, 50.
Veins, effect of carbonic acid injected into the, 28.
Vessels, forms of, 325.

Watt's indicator for steam-engines, 308.
Waves, 325.
Whewell (Rev. W.) on discussions of Bristol tides, 30.
—— on the discussion of Leith tide observations, 33.
—— on terrestrial magnetism and meteorology, 38.
—— on revising the nomenclature of the stars, 44.
—— on experiments with balloons, 55.
Whewell's anemometer, Mr. S. Harris on the working of, 36.
Woods (Edward) on railway constants, 247.

Zoology, marine, 331.

INDEX II.

TO

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

Abscess, hepatic, 81.
Acid, hydrocyanic, new extemporaneous process for the production of, 54.
Ægean sea, on two remarkable marine invertebrata inhabiting the, 72.
Agricultural products of Cornwall, 83.
Air, on the temperature of the, in York minster, 29.
Allotments, on the system of small, and spade husbandry, 98.
Animal, new glirine, from Mexico, 70.
Animals of New Holland, geographical distribution of the, 68.
Arnott's stove, Mr. J. N. Hearder on, 105.
Artesian well, strata penetrated in sinking an, at Plymouth, 63.
Ascites, extraordinary case of albuminous, with hydatids, 81.
Asthma, 80.
Atkinson (Joseph) on rain, at Harraby, near Carlisle, 30.
Austria, freshwater fish of, 71.
Axmouth, landslip of, 64.

Ball (Robert) on the destruction of plants by animal odour, 76.
Bartlett (Mr.) on the post-tertiary formations of Cornwall and Devon, 61.
—— on animal and vegetable physiology, 77.
Bateman (J.) on the use of the sliding rules, 42.
Bellamy (Dr. P. F.) on two Peruvian mummies, 75.
Bellamy (J. C.) on Devonian fossils, 64.
—— on the distribution, &c., of the mammals of Devonshire, 68.

Blindness, case of, 81.
Bodmin, fossil organic remains of, 61.
Booth (A.) on spontaneous combustion, 50.
Boswarra (J.) on the heave of a copper lode, 64.
Botany, 68.
Bottles, application of caoutchouc as a stopper for, 106.
Bowman (Edmund) on determining distances by the telescope, 42.
Bowman (J. E.) on the upper Silurian rocks of Denbighshire, 59.
Breakwater, Plymouth, 99.
——, floating, 100.
Brewster (Sir David) on crystalline reflexion, 42.
Bridges, suspension, system of trussing for the roadways of, 102.
Bristol, statistics of education in the city of, 89.
Brockedon (Mr.) on caoutchouc as a stopper for bottles, 106.
Brunel (Sir J.) on the present state of the Thames tunnel, 106.
Brussels, establishment of a central statistical commission in, 98.
Buckland (Rev. Dr.) on specimens from granite quarries near Prince Town, Dartmoor, 64.
—— on models for illustration of the succession and dislocations of strata, mineral veins, &c., 67.
Bunsen (Prof.) on the radical of the kakodyle series, 55.
Butter (Dr. J.) on the pathology and cure of squinting, 79.

Caldwell (Dr.) on the varieties of the human race, 75.
Caoutchouc, application of, as a stopper for bottles, 106.
Cardinia, Agassiz, on the genus, as characteristic of the lias formation, 65.
Cecidomya Tritici, 72.
Chatfield (W.) on Truscott's plan for reefing paddle-wheels, 102.
Chemical action, restrained, 51.
Chemistry, 43.
Chock channels, Captain Couch's, 102.
Christie (Prof.) on the preservation of magnetic needles and bars from oxidation by the electrotype process, 41.
Chronometers, application of a coating of gold to the steel balance-springs of, 41.
Circles, instrument for drawing, in perspective, 42.
Clergy of the established church in Scotland, stipends of the, 96.
Coathupe (C. T.) on an improved sight for rifles and other fire-arms, 104.
Combustion, spontaneous, 50.
Compasses, sea, 27.
Continent, account of the monts de piété on the, 91.
Copper, action of sea water on, 77.
Copper sheathing, causes of the increased destructibility of modern, 43.
Cornwall, post-tertiary formations of, 61.
——, fossil organic remains of the south-east coast of, 61.
——, zoology of the county of, 68.
——, flora of, 75.
——, agricultural products of, 83.
——, connexion which exists between improvements in pit-work and the duty of steam-engines in, 103.
Couch's (Capt.) chock channels, 102.
Couch (Jonathan) on the zoology of the county of Cornwall, 68.
Craig (John) on sections of the railway between Glasgow and Greenock, and Greenock and Ayr, 67.
Crustaceans, occurrence of some minute fossil, in Palæozoic rocks, 64.
Cyanogen, direct formation of, from its elements, 52.

Daltonism, 40.
Dana (Dr. Samuel L.) on determining the quantity of real indigo in the indigos of commerce, 49.
Dartmoor, granite quarries of, 105.
Daubeny (Prof.) on manures considered as stimulants to vegetation, 47.
—— on the disintegration of the dolomitic rocks of the Tyrol, 48.
—— on a portable botanical press, 77.
Dawson (Mr.) on the landslip of Axmouth, 64.
Deafness, case of, 81.
Deakin's (Dr. R.) registers of meteorological instruments at the baths of Lucca in 1840, 42.
De Moleyns (Mr.) on recent discoveries in voltaic combination, 42.
—— on the nature and properties of the new element, or product of electrical action mentioned by Schönbein, 57.
Denbighshire, upper silurian rocks of, 59.
Derry's (Samuel) statistical report of patients of the Plymouth public dispensary, during the years 1838–1840, 83.
Devon, post-tertiary formations of, 61.
——, flora of, 75.
Devonport, statistics of, 82.
Devonshire, distribution, &c., of the mammals of, 68.
Dickson (Sir D. J. H.) on an extraordinary case of albuminous ascites, with hydatids; of five cases of hepatic abscess, and of two cases of phthisis, 81.
Dispensary, Plymouth public, statistical report of patients of the, during 1838-1840, 83.
Dukinfield, income and expenditure of certain families of the working classes in, 90.
Dumbness, case of, 81.
Dury (Rev. T.) on sea compasses, 27.
Dent (E. J.) on the application of a coating of gold to the steel balance springs of chronometers, 41.

Education, natural history as a branch of, 77.
——, statistics of, in Bristol, 89.
——, state of, in the polytechnic school at Paris, 96.
Eel, habits of the, 71.
Electrical action mentioned by Schönbein, nature and properties of the new element, or product of, 57.
Electrotype process, preservation of magnetic needles and bars from oxidation by the, 41.
Empyema, 82.
Enamel, capsular investment of the, 17.
Enys (J. S.) on the connexion which exists between improvements in pit-work and the duty of steam-engines in Cornwall, 103.
Epithelium, structure of the, 15.
Equation, algebraic, relation of Sturm's auxiliary functions to the roots of an, 23.
Eye, human, on two new fasciæ connected with the muscles of the, 80.

Fire, possibility of, from the use of hot water in warming buildings, and of explosions in steam-engine boilers, 49.
Fire-arms, improved sight for, 104.
Fish, freshwater, of Austria, 71.
Fishes, marine, three new genera of, from Van Diemen's Land, 71.
Flues, descending, their application to the purposes of ventilation, 105.
Forbes (E.) on two remarkable marine invertebrata inhabiting the Ægean sea, 72.
Fossil organic remains of Cornwall, and of Bodmin and Menheniott, 61.
Fossils, discovery of, on Great Hangman Hill, North Devon, 64.
——, on copying, by a galvanic deposit, 67.
Fowler (Dr.) on a case of deafness, dumbness and blindness, with remarks on the muscular sense, 81.
Fowler (Mr.) on a new calculating machine, 39.
Fownes (G.) on the direct formation of cyanogen from its elements, 52.
Fripp (Mr.) on the statistics of education in the city of Bristol, 89.

Geography, physical, 59.
Geology, 59.
Gilbert (Mrs. Davies) on a system of small allotments and spade husbandry, 98.
Gold, application of a coating of, to the steel balance-springs of chronometers, 41.
Granite quarries of Dartmoor, 105.
——, specimens from, near Prince Town, Dartmoor, 64.
Grantham (J.) on a plan of disengaging and reconnecting the paddle-wheels of steam-engines, 102.
Gray (J. E.) on the geographical distribution of the animals of New Holland, 68.
—— on a new glirine animal from Mexico, 70.
Grellet (Mr.) on an instrument for drawing circles in perspective, 42.
Gurney (G.) on the possibility of fire from the use of hot water in warming buildings, and of explosions in steam-engine boilers, 49.
Gutch's (W. G) notice of certain barometers invented by Mr. Bursill, 42.

Harding (Major) on the discovery of fossils on Great Hangman Hill, N. Devon, 64.
Harraby, near Carlisle, rain at, 30.
Harris (W. S.) on Capt. Couch's chock channels, 102.
Hearder (J. N.) on Arnott's stove, and the construction of descending flues, and their application to the purposes of ventilation, 105.
Heat, refraction of, 25.
Henslow (Prof.) on Cecidomya tritici, 72.
Herschel (Sir J. F.W., Bart.) on photographs, 40.
Hewett (Capt.) on the tide of the north sea, 32.
Heywood (James) on the state of education in the polytechnic school at Paris, 96.
Hopkins (Thomas) on the influence of mountains on temperature in the winter in certain parts of the northern hemisphere, 28.
Hore (Rev. W. S) on the flora of Devon and Cornwall, 75.
Hull, condition of the working-classes in, 85.
Human race, varieties of the, 75.
Hunt (Mr. R.) on the influence of the ferrocyanate of potash on the iodide of silver as a photographic preparation, 47.
Husbandry, spade, on the system of small allotments and, 98.
Hydrogen, production of sulphuretted, 57.

Indices, refractive, theoretical computation of, 24.
Indigo, quantity of real, in the indigo of commerce, 49.
Infusoria, deposits in springs, rivers and lakes, from the existence of, 72.
Integrals, definite, machine for calculating the numerical values of, 35.
Invertebrata, marine, two remarkable, inhabiting the Ægean sea, 72.
Ireland, loan funds in, 93.

Johnson (W.) on the granite quarries of Dartmoor, and their railways and machinery, 105.
Jordan (T. B.) on copying fossils by a galvanic deposit, 67.

Kakodyle series, radical of the, 55.
Kingston-upon-Hull, condition of the working-classes in, 85.

Laing (D.) on Smith's wire ropes, 106.
Lakes, deposits in, from the existence of infusoria, 72.
Landslip of Axmouth, 64.
Lankester (Dr. E.) on the production of sulphuretted hydrogen by the action of ve-

getable matter on solutions containing sulphates, 57.
Lankester (Dr. E.) on deposits in springs, rivers and lakes, from the existence of infusoria, 72.
Lee's (John Campbell) notice of a meteorological journal for the year 1840, kept by, 32.
Lemon (Sir C., Bart.) on the agricultural products of Cornwall, 83.
Lepidosiren, two specimens of, from Macartney Island, 72.
Lias formation, on the genus Cardinia as characteristic of the, 65.
Lichens, white crystalline substance obtained from, 53.
Liebig (Prof.), abstract of a letter from, to Dr. Playfair, 53.
Light, certain points of the wave-theory of, 25.
——, some investigations on the phænomena of thin plates in polarized, 26.
Lloyd (Rev. Prof.) on some investigations on the phænomena of thin plates in polarized light, 26.
—— on simultaneous changes of the magnetic elements at different stations, 26.
Loan funds in Ireland, 93.
Lode, copper, heave of a, 64.
Longchamps (M. E. de Selys), projet d'observations annuelles sur la périodicité des oiseaux, 73.
Lucas (P. B.) on two new fasciæ connected with the muscles of the human eye, 80.

Macgowan (Dr.) on empyema, 82.
Machine for calculating the numerical values of definite integrals, 35.
——, new calculating, 39.
Machinery of the granite quarries of Dartmoor, 105.
Magnetic elements, simultaneous changes of the, at different stations, 26.
Magnetic needles and bars, preservation of, from oxidation, 41.
Mammals of Devonshire, distribution, &c., of the, 68.
Manchester, income and expenditure of certain families of the working classes in, 90.
Manures considered as stimulants to vegetation, 47.
Marshall (John) on the fall of rain in low and high ground near Hallsteads in Cumberland, 42.
Mathematics, 23.
Mechanics, 99.
Medical science, 77.
Menheniott, on the fossil organic remains of, 61.
Mexico, new glirine animal from, 70.
Mineral veins, models for illustration of the succession and dislocations of, 67.
Monts de piété of Rome, Paris, and other cities on the continent, 91.
Moore (Dr. E.) on the discovery of organic remains in a raised beach in the limestone cliff under the Hoe, at Plymouth, 62.
Moore (Dr. E.) on the strata penetrated in sinking an Artesian well at the Victoria spa, Plymouth, 63.
Moseley (Henry) on a machine for calculating the numerical values of definite integrals, 35.
Mountains, influence of, on temperature in the winter in certain parts of the northern hemisphere, 28.
Mount Batten, on specimens from the slaty rocks of, 64.
Mummies, on two Peruvian, 75.
Muscles of the human eye, on two new fasciæ connected with the, 80.

Nasmyth (Mr.), letters respecting his paper on the structure of the teeth, 3.
—— on the microscopic structure of the teeth, 14.
—— on the structure of the epithelium, 15.
Natural history as a branch of education, 77.
Neild (W.) on the income and expenditure of certain families of the working classes in Manchester and Dukinfield, in 1836 and 1841, 90.
New Holland, geographical distribution of the animals of, 68.
Nitrogen, on determining the amount of, in organic bodies, 54.
Northern hemisphere, influence of mountains on temperature in winter in certain parts of the, 28.
North sea, tide of the, 22.

Oiseaux, projet d'observations annuelles sur la périodicité des, 73.
Opium, value of, as a remedy in rheumatism, 78.
Opossum, great dog-headed, 70.
Organic remains, discovery of, in a raised beach, in the limestone cliff, under the Hoe, at Plymouth, 62.
——, fossil, of Cornwall, and of Bodmin and Menheniott, 61.
Owen's (Prof.) letters respecting Mr. Nasmyth's paper on the structure of the teeth, 4.
—— on a Thylacinus, the great dog-headed opossum, 70.

Paddle-wheel and screw, propulsion of vessels by the trapezium, 101.
Paddle-wheels, Truscott's plan for reefing, 102.
—— of steam-engines, plan for disengaging and reconnecting the, 102.
Palæozoic rocks, occurrence of some minute fossil crustaceans in, 64.
Paracyanogen, production of silicon from, 54.
Paris, monts de piété of, 91.
——, state of education in the polytechnic school at, 96.
Parnell (E. A.) on restrained chemical action, 51.
—— on some subjects connected with the sulphocyanides, 51.

Patterson (R.) on natural history as a branch of education, 77.
Peach (C. W.) on the fossil organic remains of the south-east coast of Cornwall, and of Bodmin and Menheniott, 61.
Peruvian mummies, on two, 75.
Phillips (John), letter respecting Mr. Nasmyth's paper on the structure of the teeth, 3.
—— on the temperature of the air in York Minster, 29.
—— on rain at York, 30.
—— on the occurrence of some minute fossil crustaceans in Palæozoic rocks, 64.
Photographic preparation, influence of the ferrocyanate of potash on the iodide of silver as a, 47.
Photographs, 40.
Phthisis, 81.
Physics, 23.
Physiology, animal and vegetable, comparative view of, 77.
Pines, on some species of European, 76.
Pit-work, connexion which exists between improvements in, and the duty of steam-engines in Cornwall, 103.
Plants, destruction of, by animal odour, 76.
Playfair (Dr.), abstract of a letter from Prof. Liebig to, 53.
Plymouth breakwater, 99.
Plymouth, stratified and unstratified volcanic products near, 61.
——, discovery of organic remains in the limestone cliff, under the Hoe at, 62.
——, strata penetrated in sinking an Artesian well at the Victoria spa at, 63.
——, statistics of, 82.
——, statistical report of patients of the public dispensary, during 1838–1840, 83.
Polytechnic school at Paris, state of education in the, 96.
Pontia, specimens of, 72.
Porter (Henry J.) on the monts de piété of Rome, Paris, and other cities on the continent, 91.
—— on the loan funds in Ireland, 93.
Potash, ferrocyanate of, influence of the, on the iodide of silver, as a photographic preparation, 47.
Powell (Prof.) on the theoretical computation of refractive indices, 24.
—— on the refraction of heat, 25.
—— on certain points of the wave-theory of light, 25.
Pratt (S. P.) on specimens from the slaty rocks of Mount Batten, 64.
Prideaux (J.) on copper which had been acted on by sea water, 77.
—— on the causes of the increased destructibility of modern copper sheathing, 43.
Prince Town, Dartmoor, on specimens from granite quarries, near, 64.

Quarries, granite, of Dartmoor, 105.
Quetelet (Prof.) on the importance of keeping registers of the physical and moral world, 96.
Quetelet (Prof.) on the establishment of a central statistical commission in Brussels, 98.

Race, varieties of the human, 75.
Railway, notice of sections of the, between Bristol and Bath, 67.
——, between Glasgow and Greenock, and Greenock and Ayr, 67.
Railways of the granite quarries of Dartmoor, 105.
Rain, researches on, at York, 30.
——, at Harraby, near Carlisle, 30.
Reid (Dr. D. B.) on the ventilation of ships, 82.
Rendel (J. M.) on a system of trussing for the roadways of suspension bridges, 102.
Rennie (G.) on the propulsion of vessels by the trapezium paddle-wheel and screw, 101.
Rheumatism, value of opium as a remedy in, 78.
Richardson (Dr.) on three new genera of marine fishes from Van Diemen's Land, 71.
Rifles, improved sight for, 104.
Rivers, deposits in, from the existence of infusoria, 72.
Rocks, dolomitic, of the Tyrol, disintegration of the, 48.
——, upper Silurian, of Denbighshire, 59.
——, palæozoic, occurrence of some minute fossil crustaceans in, 64.
Rome, account of the monts de piété of, 91.
Ropes, Smith's wire, 106.
Rumball (Mr.) on asthma, 80.
Ryland (A.) on the income of scientific and literary societies, and the amount paid for rates and taxes in 1840, 95.

Sanders (William) on sections of the railway between Bristol and Bath, 67.
Santorin, map of, 68.
Saxicava rugosa, geological changes produced by the, in Plymouth Sound, 66.
Schunk (M.) on a white crystalline substance obtained from lichens, 53.
Science, medical, 77.
Scotland, stipends of the clergy of the established church in, 96.
Screws, new construction of a die-stock for cutting, 106.
Sense, muscular, 81.
Sepiadæ, colossal, 73.
Sheffield, economic statistics of, 87.
——, vital statistics of, 88.
Ships, ventilation of, 82.
Silicon, production of, from paracyanogen, 54.
Silver, iodide of, influence of the ferrocyanate of potash on the, as a photographic preparation, 47.
——, molybdic, 58.
Skin, pustular disease hitherto undescribed by writers on diseases of the, 77.
Sliding rule, use of the, 42.
Societies, income of literary and scientific, in 1840, 95.

Societies, amount of rates and taxes paid by literary and scientific, 1840, 95.
Smith (Col. Hamilton) on the colossal sepiadæ, 73.
Solomon (J. V.) on the treating of squinting, 80.
Springs, deposits in, from the existence of infusoria, 72.
Square (W. J.) on a case of empyema, 82.
Squinting, pathology and cure of, 79.
Statistical commission, establishment of a central, in Brussels, 98.
Statistics, 82.
——, economic, of Sheffield, 87.
——, vital, of Sheffield, 88.
—— of education in the city of Bristol, 89.
Steam-boats, shield to protect the paddle-wheels of, from the action of the sea, 101.
Steam-engines, plan of disengaging and reconnecting the paddle-wheels of, 102.
—— in Cornwall, connexion which exists between improvements in pit-work and the duty of, 103.
Stonehouse, statistics of, 82.
Strata, models for illustration of the succession and dislocations of, 67.
Strickland (H. E.) on the genus Cardinia, as characteristic of the lias formation, 65.
—— on a map of Santorin, 68.
Stuart (W.) on the Plymouth breakwater, 99.
Sturm's auxiliary functions, relation of, to the roots of an algebraic equation, 23.
Sugar, composition of crystallized diabetic, 54.
Sulphocyanides, some subjects connected with the, 51.
Sylvester (Prof.) on the relation of Sturm's auxiliary functions to the roots of an algebraic equation, 23.

Taylor (Capt.) on a floating breakwater, 100.
—— on a shield to protect the paddle-wheels of steam-boats from the action of the sea, 101.
Taylor (John) on the water-power at Wheal Friendship mine, 106.
Teeth, microscopic structure of the, 14.
Telescope, determination of distances by the, 42.
Temperature, influence of mountains on, in the winter, 28.
Thompson (Dr. T.) on the value of opium as a remedy in rheumatism, and on the circumstances which should regulate its employment, 78.
Thomson (Dr. A. T.) on a pustular disease hitherto undescribed by writers on diseases of the skin, 77.
Thomson (Dr. R. D.) on the new process for the production of hydrocyanic acid for medical use, 54.
—— on the composition of crystallized diabetic sugar, 54.
Thomson (Dr. T.) on two lepidosirens from Macartney Island, 72.
Thylacinus, account of a, 70.
Tide of the North Sea, 32.
Transactions of the Sections in 1839, addendum to the Report of the, 1.
Tripe (Dr.) on some specimens of Pontia, 72.
Truscott's plan for reefing paddle-wheels, 102.
Trussing, system of, for the roadways of suspension bridges, 102.
Tunnel, Thames, present state of the, 106.
Tweedy (Mr.) on molybdic silver, 58.
Tyrol, disintegration of the dolomitic rocks of the, 48.

Van Diemen's Land, three new genera of marine fishes from, 71.
Varrentrapp (Dr.) on determining the amount of nitrogen in organic bodies, 53.
Vegetation, manures considered as stimulants to, 47.
Ventilation, on descending flues, and their application to the purposes of, 105.
Vessels, propulsion of, by the trapezium paddle-wheel and screw, 101.
Volcanic products, stratified and unstratified, near Plymouth, 61.

Walker (W.) on the geological changes produced by the Saxicava rugosa in Plymouth Sound, 66.
Wartmann (Prof. Elie) on Daltonism, 40.
Water-power at Wheal Friendship mine, 106.
Wave-theory of light, certain points of the, 25.
Wheal Friendship mine, water-power at, 106.
Whitworth (Mr.) on a die-stock for cutting screws, 106.
Widdrington (Capt.) on the habits of the eel, and on the freshwater fish of Austria, 71.
—— on some species of European pines, 76.
Will (Dr.) on determining the amount of nitrogen in organic bodies, 53.
Williams (Rev. D.) on the stratified and unstratified volcanic products in the neighbourhood of Plymouth, 61.
Woollcombe (H.) on the statistics of Plymouth, Stonehouse, and Devonport, 82.
Working classes, in Kingston-upon-Hull, condition of the, 85.
——, income and expenditure of certain families of the, in Manchester and Dukinfield, 90.

York minster, temperature of the air in, 29.
York, rain at, 30.

Zoology, 68.
—— of the county of Cornwall, 68.

THE END.

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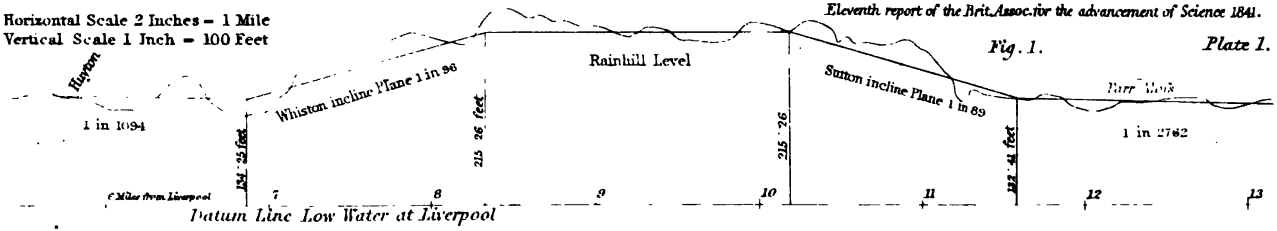

Fig. 2.

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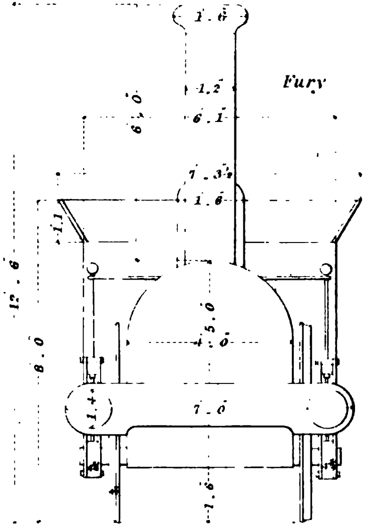

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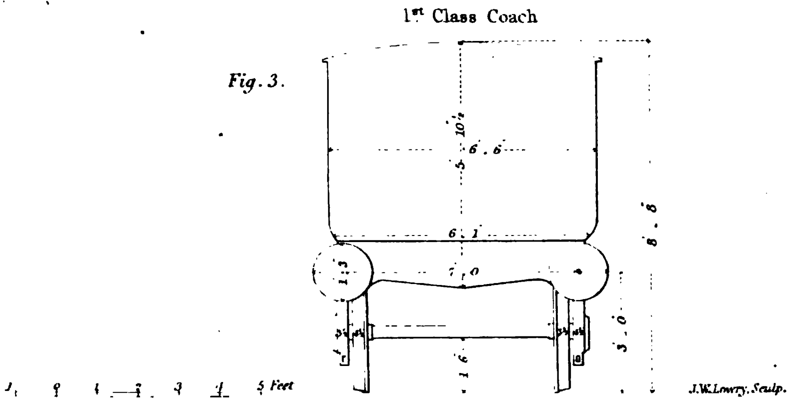

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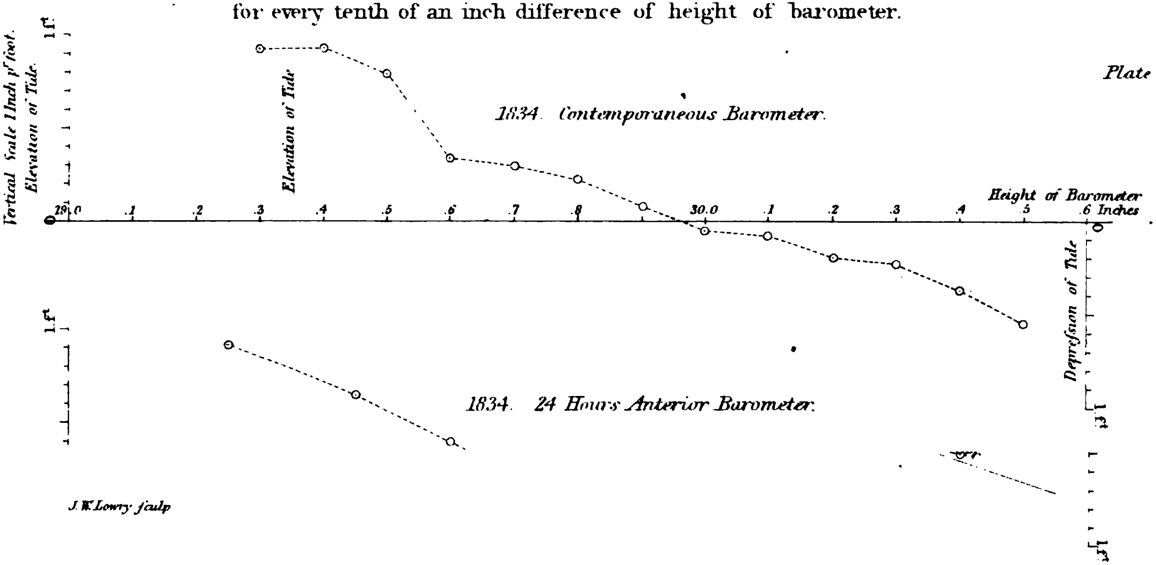

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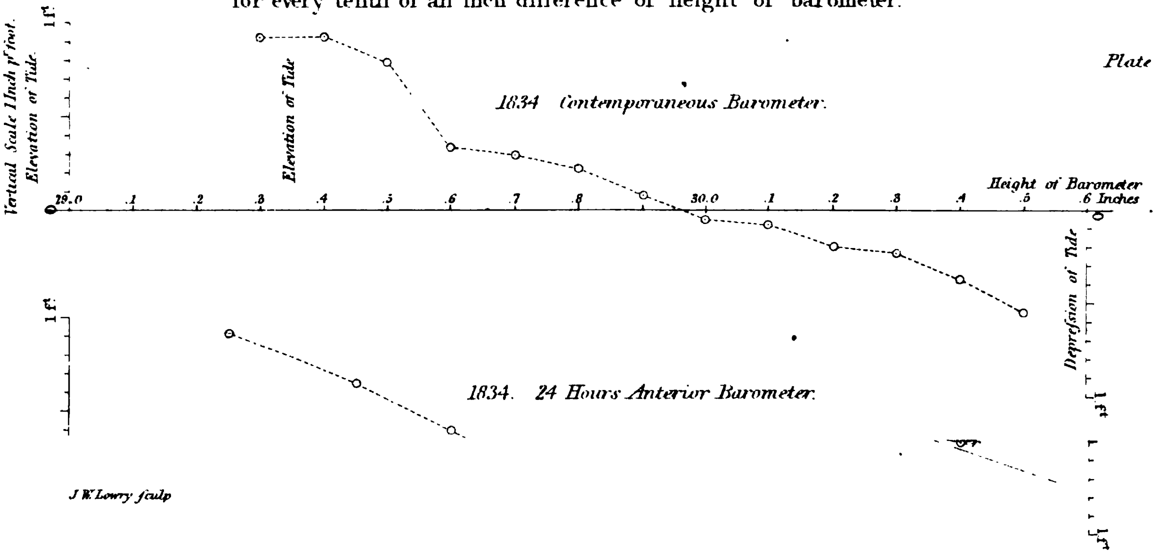

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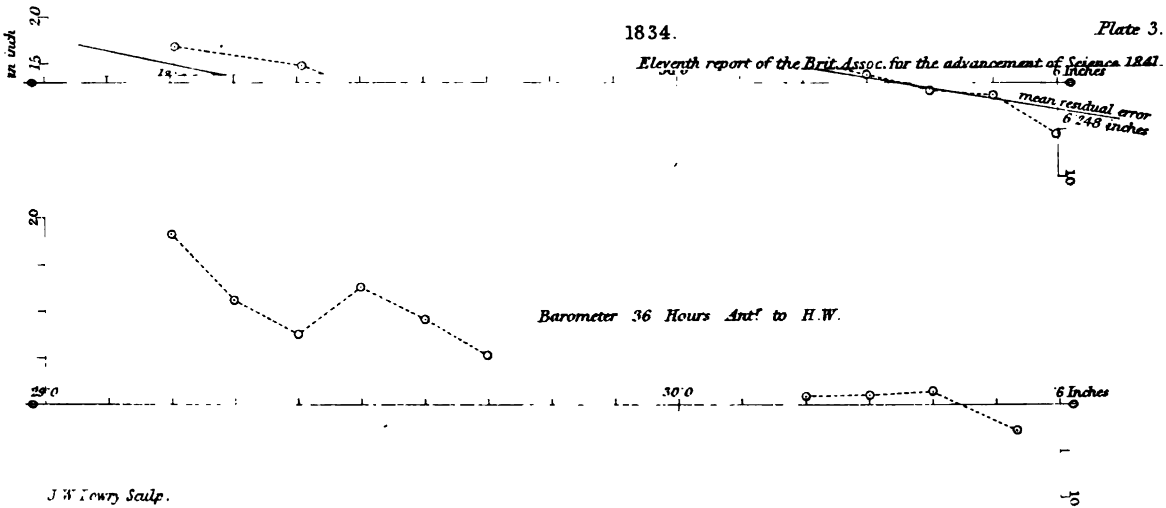

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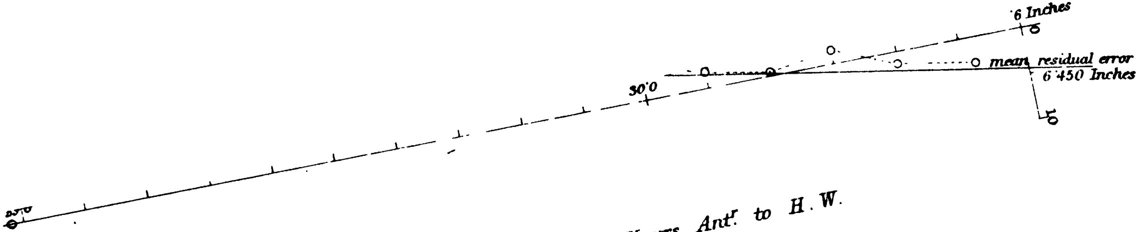

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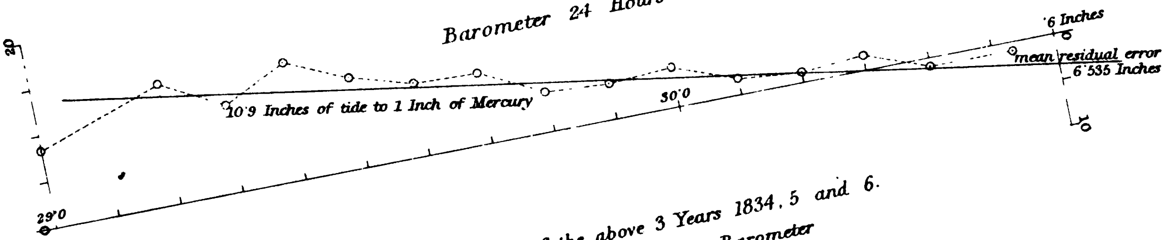

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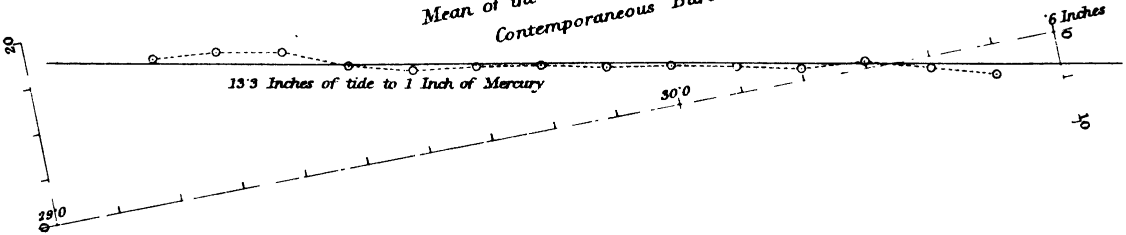

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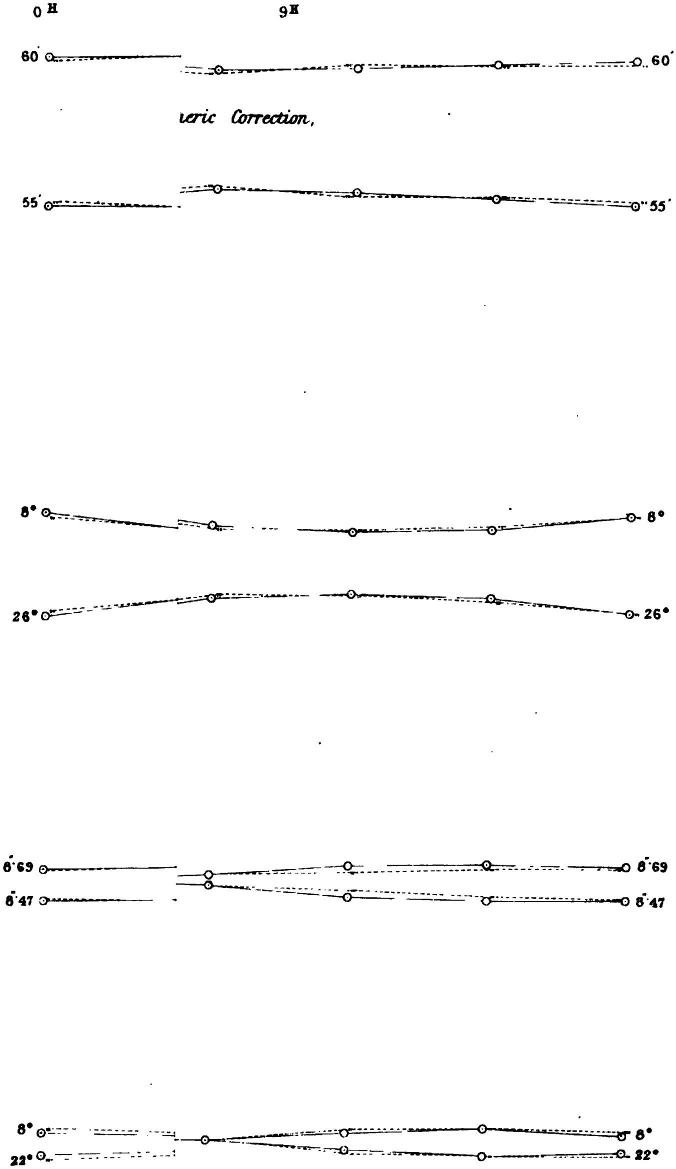

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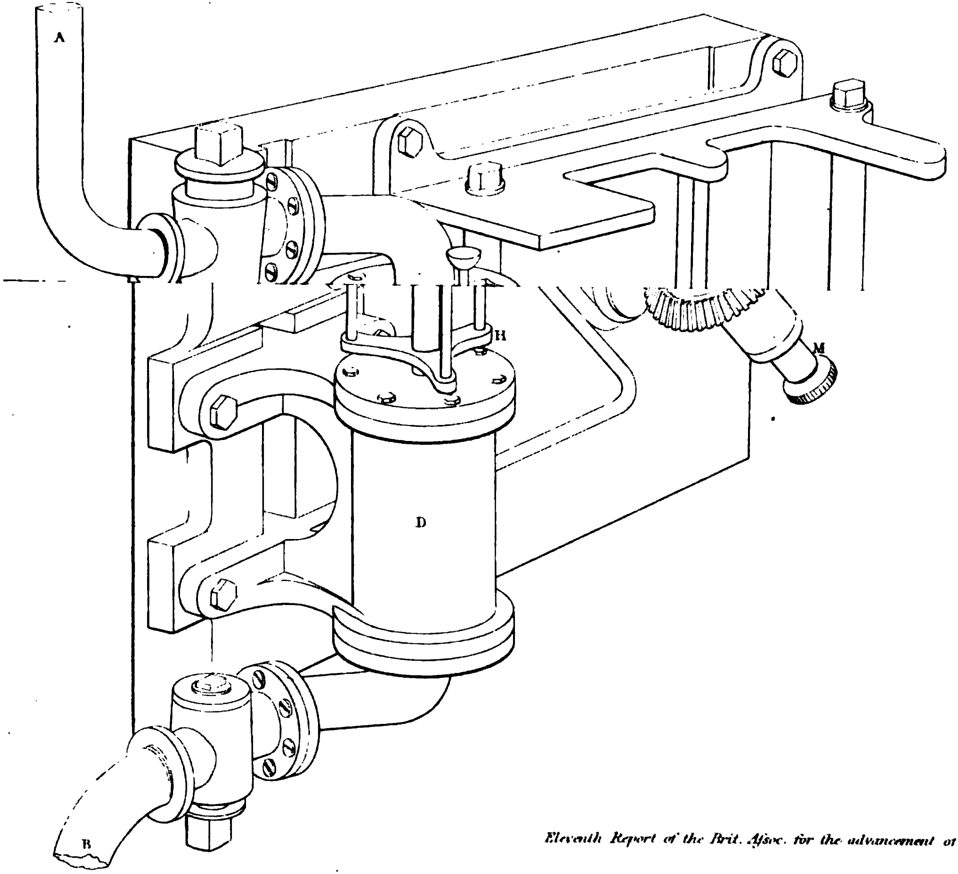

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